Silvicultural management of smallholder commercial tree plantations in the Southern Highlands of Tanzania: characterization and influencing factors

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Tiivistelmä/Referat – Abstract

Small-scale commercial tree plantations are considerably increasing in the Southern Highlands of Tanzania, and offer an alternative to large-scale plantations to reduce the increasing gap in supply and demand of roundwood. Currently, some donor-funded incentive schemes are taking place in the area to provide extension to farmers. This extension aims to develop rural areas by engaging farmers to plant and sustainably manage commercial tree plantations. Application of silvicultural activities up to the standards is essential for the profitability and productivity of commercial tree plantations. This study aims to characterize and analyze the factors influencing silvicultural management of smallholder tree plantations; in order to find the possible issues, which are currently hindering a better success of tree-planting initiatives.

The research took place in twelve different villages, in the districts of Ludewa, Njombe, Makete and Mufindi. Data was collected through semi-structured questionnaires at household level and field surveys to cross-check the information given by the farmers. A total of 114 farmers were interviewed and 44 smallholder plantations were surveyed.

Complete and adequate silvicultural management was generally low. However, nearly all farmers believed that their woodlots performed well. The results indicate that current silvicultural management satisfied most of the farmers since markets existed also for lower quality wood, and farmers were able to only allocate some of their labour for silvicultural management (tree planting was a secondary livelihood option for them). However, the current level of management did not provide higher quality wood required for industrial purposes. The management applied differed between woodlots of the same household and between seasons. External support from an incentive scheme (e.g. free/subsidized seedlings and extension), participation in tree-growers' associations and favorable attitudes, influenced positively the level of certain management activities applied (i.e. site preparation, weeding and firebreaks). The age of the farmer, the number of household members, the number of children at school, the total household land area, and the number of years planting trees; also had an effect on the level of silvicultural management.

The results suggest that training and technical advice given to farmers on silvicultural management should be more consistent, detailed (i.e. timing, frequency and intensity of activities) and dependent on the climatic conditions and the site characteristics of the tree plantations. To conclude, the creation and development of networks (such as farmers' groups and company-community partnerships) aiming to provide support to farmers beyond tree-planting schemes is likely to offer the most long-term positive outcomes in smallholder commercial tree planting. Ultimately, for extension to be most successful it must be relevant to farmers' needs. Farmers receiving extension and extension providers should share similar goals – i.e. extension should target to a specific group of farmers. Accordingly, it is advisable to consider if the extension for rural development can have the same target group and provide the same incentives as the extension for commercial tree planting.

Avainsanat – Nyckelord – Keywords

Tanzania, smallholder, tree plantation, silvicultural management, forestry extension, incentives

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PREFACE

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Helsinki, March 2019

Elisabet Rams Beltrán

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LIST OF ACRONYMS AND ABBREVIATIONS

DBH – Diameter at Breast Height

MNRT – Ministry of Natural Resources and Tourism of Tanzania

PFP – Private Forestry Programme

QCA – Qualitative Content Analysis

STG - Smallholder Tree Grower

TGA – Tree-Growers' Association

VLUP – Village Land Use Plan

VSLA – Village Savings and Loans Association

1. INTRODUCTION

1.1. Tree planting expansion in Tanzania

The prevalence of deforestation and forest degradation in the tropics is well known. Tanzania is not an exception; the 55% (equivalent to 46 M ha) of total land area covered by forest has been decreasing at a rate of 372 000 ha/yr during the period from 1995 to 2015 (FRA 2015). Nearly all of its forests are classified as naturally regenerated forests.

Tanzania has experienced a relatively high economic growth during the last decade, on average 6-7% a year (World Bank 2018). However, the gains have been very unevenly distributed, and poverty reduction has been primarily in the urban centres (World Bank 2018). Economic development together with land use intensification, forest loss and increasing demand of forest products, has led to considerable expansion of tree plantations. The estimated forest plantation area in Tanzania varies from 200,000 to 550,000 hectares mostly located in the Southern Highlands (Mankinen et al. 2016).

Tanzania is one of the few countries in the world which still has land available as well as the proper climatic conditions and soil fertility required for tree planting activities (PFP 2015). The Southern Highlands of Tanzania have a great potential to satisfy demand of wood products in the country. Demand of wood products, such as timber and poles for construction, electricity and communications has kept increasing sharply from both local and international markets (Indufor 2011). The demand for industrial wood from plantations is at the present 1.5 million m^3 and it is forecasted to rise to 3.87 million m^3 by the year 2025 (PFP 2015). However, the current sustainable supply of wood from plantations is 1.1 million m^3 based on the existing forest resources. Thus, increasing the area of tree plantations and increasing the productivity of all present and future tree plantations, is required in order to reduce the increasing gap between demand and supply.

Until recently, government-managed plantations and larger-scale industrial plantations were the only acknowledged plantations in the statistics of developing countries (Noordwijk et al. 2008). However during the last decade, the importance of smallholder

tree plantations in order to produce timber, pulpwood and environmental services has been increasingly recognized (Snelder and Lasco 2008). In this study, the term smallholder tree growers refers to small-scale farmers/households who manage areas (ownership or land-use rights) varying from less than one hectare to a maximum of a few hundred hectares, where they grow trees for commercial purposes.

1.2. Low success of state-owned industrial tree plantations and the potential of smallholder tree plantations

Globally, most industrial plantations have been established with financial support from the state (Cossalter and Pye-Smith 2003). Support and incentives which make plantations viable, where otherwise they would not be, are justified by their benefits to society, benefits such as carbon sequestration, soil protection and employment. However, without efficient, democratic and uncorrupted governments, incentive schemes to stimulate large-scale tree plantations often provide large amounts of money to relatively few people and cause considerable environmental damage and social hardship (Cossalter and Pye-Smith 2003). In the case of Tanzania, the majority of the forest industry's raw material comes from governmental plantations. Sao Hill forest plantations – located in the Southern Highlands – represent the biggest state owned plantations, established in 1970s and covering about 50 000 hectares (Held et al. 2017). In 2009, Sao Hill plantations alone produced 85% of the total industrial wood supply of Tanzanian government plantations (PFP 2015).

Sao Hill forest resources were largely secured thanks to the funding from World Bank during the Tanzanian economic crises (late 1970s – 1980s). Villagisation – resettlement of people into designated villages – was used by the Ministry of Natural Resources and Tourism to expand the plantation forestry in Mufindi district (Kangalawe 2018). However, the accelerated process of villagisation to secure World Bank funding, led to numerous conflicts on the forest project boundaries imposed by Sao Hill. Sao Hill requested customary lands owned by the locals in Mufindi district (Kangalawe 2018). In 1986, the International Monetary Fund pressured Tanzanian government to halt the state

monopoly and allow private sector to operate instead. However, with the liberalization of the market, land grabbing and contestations on the ownership of logging rights increased dramatically due the already previous conflicts with land tenure (Kangalawe 2018).

Later on (around 1992), World Bank loan ended because of the uncertainty on profit realization from these tree plantations, and subsequently Sao Hill plantations failed to expand their tree planting areas as well as skipped pruning and thinning operations (Kangalawe 2018). In 1996, Sao Hill sawmill was privatized to the Norwegian firm, Green Resources Ltd. On the coming years, governmental plantations are forecasted to decrease drastically for at least ten years due to the uneven age structure and failure to replant designated plantation areas (Indufor 2011).

Aiming to enhance relationships with nearby communities and increase social acceptance of large-scale tree plantations, the privatized firm Sao Hill started to supply tree seedlings and to provide extension on tree seedling nurseries to the adjacent rural communities.

State-owned Tanzanian plantations did not meet the expected development of forest sector. Lack of finance from the donors and insufficient resources from the state prompted the shift towards private. The liberalized economy encouraged villagers to plant their own woodlots. Nowadays, smallholder tree plantations represent more than half of the tree plantations in the Southern Highlands of Tanzania (Figure 1).

The same patern can be found in many other developing countries (Enters and Durst 2004). Nowadays the essential role of local communities to the security and sustainability of forests and plantations is increasingly recognized, and smallholder tree growing is considered as a policy option addressing the Millennium Development Goals (Snelder and Lasco 2008). Smallholder constitute more than 70% of population in Africa (AGRA 2017) and yet they have often been disregarded in the process of decision- and policy-making. But such tendency is changing and it can be perceived on the new forest policies (MRNT 2008) and the increasing donor funding into projects targeting smallholders and their involvement in the forest sector development.

Under the presence of markets, tree planting can increase rural household income if farmers are able to produce sufficient quantities of quality wood products. Furthermore, trees can serve as a saving account reducing vulnerability to unexpected expenditures (Angelsen and Wunder 2003). Just to name few, this safety net can assist farmers to buy food when their crops have suffered from climatic calamities, help families in case of illness or death of relatives, assist with payment of school fees, etc. Eighty percent of the agricultural production in the country comes from subsistence farmers who rely on manual cultivation and rain-fed production, thus making them highly vulnerable to weather shocks (IFAD 2018). Hence, income diversification plays an important role on adaptation to climate change. Furthermore, the development of forest industry in rural areas is likely to benefit communities by increasing employment opportunities and developing the infrastructure.

Smallholder tree growing has the potential to play a significant role in sustainable forest management (Snelder and Lasco 2008). Generally trees require less fertile soils than agricultural crops and can be planted in degraded lands, lands with steep slopes or marginal lands. Smaller parcels increase the chance of finding suitable land for tree planting. Therefore if trees are planted in degraded lands, the environmental services provided will increase (e.g. reducing erosion, increasing carbon stocks).

Smallholder tree planting has the potential to significantly reduce land-use conflicts compared to traditional large-scale plantations by creating a favourable environment where all stakeholders can participate (Cossalter and Pye-Smith 2003).

Finally, smallholder tree planting has the potential to increase the much needed wood supply. Frequently companies have the technical skills, technology and access to markets to sell wood products; but they lack the land, labour or raw material supply. Alternatively, smallholders may have the land and labour required to produce raw material; but have limited access to markets, and lack the technical skills and capital to invest on tree planting. In this kind of situations, arrangements between growers/landholders and industries for the production of commercial wood products –

such as out-grower schemes – create a win-win scenario from both economic and social point of view.

Smallholder tree planting has the potential to reduce poverty and ensure environmental sustainability. However, to achieve both objectives, smallholder tree planting has to be profitable and sustainable. Sustainable forest management in the context of this study is understood as managing economically viable commercial tree plantations to provide long-term benefits to stakeholders, at the same time that local livelihoods are safeguarded and negative environmental impacts are minimized.

Figure 1. Smallholder commercial tree plantations transforming the landscape in Ludewa district.

1.3. Challenges of smallholder tree planting and tree-planting projects

Forest investments, even in the tropics, require long waiting periods (15 to 20 years) before the benefits are realized. Added to the fact that most of the capital is required in the first few years during the establishment of plantations, investments in forestry can be especially challenging for small-scale investors.

Numerous previous studies have demonstrated the lack of up-to-date silvicultural knowledge, planning capacity, and skills required to maximize productivity of tree plantations in tropical countries (Byron 2001; Snelder and Lasco 2008; Kallio 2013). Commercial tree planting requires specific skills and knowledge of many silvicultural practices, including when and how to conduct site establishment, weeding, pruning, thinning, harvesting and risk protection (Evans and Turnbull 2004). Land tenure insecurity and lack of supportive legal and institutional frameworks, further limits smallholders' access to markets.

Furthermore, the country's Forest Act identified the following main challenges which are currently hindering the sustainable development of the forest sector: lack of access to finance and incentives; out-dated processing and production technology (Figure 2); insecure supply of raw material; lack of information and monitoring systems; and lack of organized marketing systems and channels (The Forest Act 2002).

Figure 2. Current extensively used processing technology in the southern highlands of Tanzania: dingdong sawmills and air drying.

To successfully develop the Tanzanian forest sector ensuring the inclusion of smallholders, the first donor-funded initiatives to support smallholder tree growing recently arrived to the Southern Highlands of Tanzania – i.e.: Private Forestry Programme (PFP) and the Forestry Development Trust.

Private Forestry Programme is a major-scale development project carried out by a third party – i.e. service provider – with funding from the Ministry for Foreign Affairs of Finland and Ministry of Natural Resources and Tourism of Tanzania. It is planned to be a long-term intervention running from 2014 to 2030. The program purpose is to increase wealth and social development both by engaging rural people to establish and sustainably manage private smallholder tree plantations and by adding value to the whole value chain of forest products (PFP 2015). In order to achieve their goals, PFP established a series of incentives (PFP 2017a).

Direct incentives consisted mainly of high quality pine and eucalyptus seedlings. Farmers belonging to a Tree-Growers' Association (TGA) and planting on land designated for tree planting in a previously prepared Village Land Use Plan (VLUP) could receive seedlings to plant up to 0.8 ha (890 seedlings) for free; from 0.8 – 5 ha (891 – 5 555 seedlings) for 50% of nursery gate cost; and more than 5 ha paying full cost. Moreover, farmers could receive TZS 45 000 (~ US$20) per hectare if circle and slash weeding were applied up to the standards during the first two growing seasons.

Indirect incentives consisted of a wide array of initiatives such as: simple mobile phone-based market information system, creation of VLUPs, promotion and development of TGAs, training of extension officers and technical advice to farmers. They created the *Forest and Wood Industries Training Centre* including sawmilling, timber drying, wood workshop and seedling nursery, which has been used for trials and trainings. PFP also created and developed *Village Savings and Loans Associations* (VSLAs) to provide microfinance and business planning support. They promoted out-grower schemes with Kilombero Valley Teak Company and New Forests Company. PFP-members have also benefited from some of the activities carried out by the Forestry Development Trust.

So far, Private Forestry Programme has reached its planting targets. Nevertheless, monitoring showed that many tree growers had not managed their woodlots properly and in consequence, many woodlots were in poor condition (PFP 2016b). Once plantations are established, proper silvicultural management is essential to maximize growth potential and to meet the market requirements concerning quantity and quality. Proper silvicultural management will determine the profitability of such plantations and thus the potential of smallholder tree growing in rural development.

So, why many of the tree growers had not managed their woodlots up to the standards, even though they were given the extension related to silvicultural management? Based on previous research, factors influencing silvicultural management include: socio-economic characteristics of the farmer and the household, characteristics of the farm, farmer's participation in farmers associations, farmer's attitudes and perceptions, farmer's skills and knowledge, support and extension received, existence of and access to attractive markets, policy and institutional context, and land tenure (Byron 2001; Pattanayak et al. 2003; Walters et al. 2005).

There is still a research gap on tree growing by smallholders compared to large-scale plantations (Snelder and Lasco 2008). Even when data and information are available, the great majority of experiences come from the Asian continent. The gap in research and literature on smallholder tree growing in Eastern Africa is vast, and the scattered information available is largely hidden in reports from donor-funded projects (Arvola et al. 2019).

The potential profitability of commercial tree plantations highly depends on the adequate implementation of the management activities up to the standards. To gain understanding about smallholder silvicultural activities and the factors that may influence the level of woodlot management provides useful information to implement tree-planting programs more effectively and efficiently. The results of this study will not only benefit the current PFP, or the Tanzanian forestry sector, but also provide valuable information to smallholder tree planting in other tropical countries.

1.4. Aim of the study

This study aims to gain understanding on a current tree-planting program in Tanzania in order to enhance the success of tree-planting initiatives. Specifically, this study has the objective to characterize the silvicultural management on smallholder commercial tree plantations in the Southern Highlands and analyze the factors that may influence such activities. Ultimately, it aims to provide meaningful recommendations to increase productivity and quality of smallholder tree plantations. The results of this study may also be applicable in other developing countries within a similar context.

Thereby, the research questions are:

(1) What silvicultural activities do smallholder tree growers apply for the management of their woodlots? How and when are these implemented?
(2) What perceptions and rationale do STG have for silvicultural management?
(3) What factors influenced the adoption or the level of silvicultural management?
(4) What improvements could be done by organizations providing external support so that farmers would further engage in the management activities of their woodlots?

And the corresponding hypotheses are:

(1) Farmers in general do not prioritize the management of tree plantations. Silvicultural activities are randomly and seldom applied.
(2) Farmers have the generalized perception that silvicultural management is not crucial for the performance of tree plantations; trees require little input after they are planted, if any. So, farmers do not perceive the benefits of managing the woodlots.
(3) Farmers silvicultural management activities are influenced by the socio-economic characteristics of the farmer and the household; characteristics of the farm; extension and external support received; farmer's participation in tree growers associations; farmer's attitudes and perceptions towards silvicultural

activities; farmer's skills and knowledge; and, farmer´s access to attractive markets.

(4) Farmer's access to capital and further extension on tree planting engages farmers to the management activities of their woodlots. However, favourable policies, the development of forest industry – including networks which allow the cooperation and communication between all stakeholders – and farmers' access to markets will play the most significant role ultimately.

2. THEORETICAL FRAMEWORK

2.1. Theoretical framework of the study

The theoretical framework of this study consists in a variety of approaches that have been previously used to study the factors behind farmer's decisions to implement or, to not implement, better silvicultural management.

There are many socio-economic factors, perceptions (i.e. attitudes, beliefs), motivations and experiences that may have an effect on the farmer's willingness and ability to carry out certain activities such as tree planting and stand management. Several studies in the tropics have found that these factors affect farmers' tree planting (Mahapatra and Mitchell 2001; Pattanayak et al. 2003; Kallio 2013; Cheserek et al. 2013) and management activities (Amacher et al. 1993; Summers et al. 2004; Walters et al. 2005; Kallio 2013).

Farmer's choices depend on the particular circumstances they found themselves and the way the farmer perceives these circumstances (Lamb 2011). Different farmers have different priorities, for instance, farmers aiming to reduce risks by diversifying the income may not be as eager to manage their woodlots compared to farmers which aim to maximize the profits. In most of the cases, the farmers' decision will be highly influenced by the opportunity cost of the other possible land uses (Lamb 2011). Farmers who apply silviculture vary in knowledge, capacities and interests, and each of these can change over time (Walters et al. 2005).

Therefore, there is a wide variety of factors which may influence silvicultural management. These range from characteristics of the individual users and the local environment to more broader geographical, economic and political circumstances (Walters et al. 2005). Characteristics of the individual users include socio-economic characteristics of the farmer (e.g.: age, education, gender) and the household (e.g.: income, assets, landholdings, labour force); the silvicultural skills and knowledge; and, attitudes and perceptions towards tree planting. Local environment refers to the

participation of farmers' associations, information sharing, traditional knowledge, the training and supports received for tree planting, location and biophysical characteristics of the tree plantations and incidence of climatic calamities. Lastly the wider context includes forest-related policies and institutions, land tenure security, and existence of an attractive market and access to it.

In an extensive review of empirical studies, Pattanayak et al. (2003) organized the factors influencing the adoption of agricultural and forestry technology by smallholders in five key determinants: household preferences, resource endowments, market incentives, bio-physical factors and risk and uncertainty. The author concludes that the first two determinants are the most common factors studied but the adoption behaviour is most likely influenced by risk, bio-physical and resource factors; namely credit, savings, prices, market constraints and plot characteristics are potentially important determinants, which have not been studied adequately.

In a comparative study including research from over 30 countries, Byron (2001) identifies four key features which are common to all the cases where widespread sustainable tree planting has succeeded, and emphasizes that all four are necessary and therefore, failure on any one can be a guarantee of failure overall. These four key elements are: (1) secure rights and access to the land and the future trees, (2) available production technology (knowledge, quality seedlings, tools, credit, etc), (3) capacity to protect the trees until maturity from any risks (fire, diseases, theft, etc), and (4) existence of market incentives (e.g.: reliable future demand, price premiums) and farmer's access to the market.

Similarly, Noordwijk et al. (2008) inside the book by Snelder and Lasco (2008), which aimed to develop a framework for future research and practice on smallholder tree growing, identify six barriers to sustainable forest management: (1) unclear land tenure and land-use restrictions, (2) lack of access to high quality planting material, (3) lack of management skills and information, (4) overregulation, (5) lack of rewards for the environmental services provided by trees, and (6) lack of supportive legal and institutional frameworks for STG.

Because real world characteristics are complex and vary between specific locations, Walters et al. (2005) encourages considering all the possible farmers' perspectives holistically and adapting them for a specific context and a particular situation. Therefore it embraces to apply a methodology using any quantitative and qualitative methods which are available and suit the best for answering the questions of interest. For this purpose, the same author affirms that open-ended *why* questions would identify the potential influence of different perspectives. These *why* questions, should be answered first by the researchers based on information from a variety of sources such as: field-based surveying, professional opinion or even personal experiences among others (Walters et al. 2005).

Following the literature previously reviewed, this study was realized using a comprehensive and multidisciplinary approach to determine why or, why not, farmers are conducting different silvicultural management activities at different levels of engagement.

Firstly, the following information was gathered: farmer's and household's socio-economic characteristics, farm characteristics, tree planting activity and the management activities applied, extension and support received, participation in farmer's associations, and attitudes and perceptions towards silvicultural management. Farmer's rationale (attitudes, perceptions, skills, knowledge) was gathered by open-ended *why* questions and by pre-established statements that farmer's had to agree, disagree or *Don't know*. The statements were formulated based on the knowledge gathered by local and international experts on the study area, and carefully designed so that farmers would not always agree or always disagree, but they would rather have to think twice about the answer.

Then, based on the variety of different answers and the diversity of the farmers, certain variables were selected and linked to the silvicultural management activities. The variables selected were: gender, age, education level, number of household members, number of children at school, annual household income classification, percentage of tree planted area, total household area, number of years planting trees, external support (and

number of direct incentives received) from a major forestry program, membership (and years of membership) to a tree growers association, average distance from household to the woodlots and, amount of permanent and temporary workers. Furthermore, a set of different perceptions and attitudes, were also linked to the level of silvicultural management applied.

This study was mainly centred on the characteristics of the individual users and the factors relative to the local conditions. However, due the lack of resources and the difficulty to assess, the biophysical characteristics of the tree plantations could not be taken into account. Moreover, the influence of markets and access to markets on the tree planting activities was also discussed, based to some extent on recent studies that took place in the same study area. Because of the extent of a master's thesis study, the influence of forest-related policies and institutions could not be analyzed.

Figure 3 was prepared to help understand the stakeholders which participate in the context of this study, and the relationships between them. In addition, Table 1 summarizes the main interests of each stakeholder and their key responsibilities.

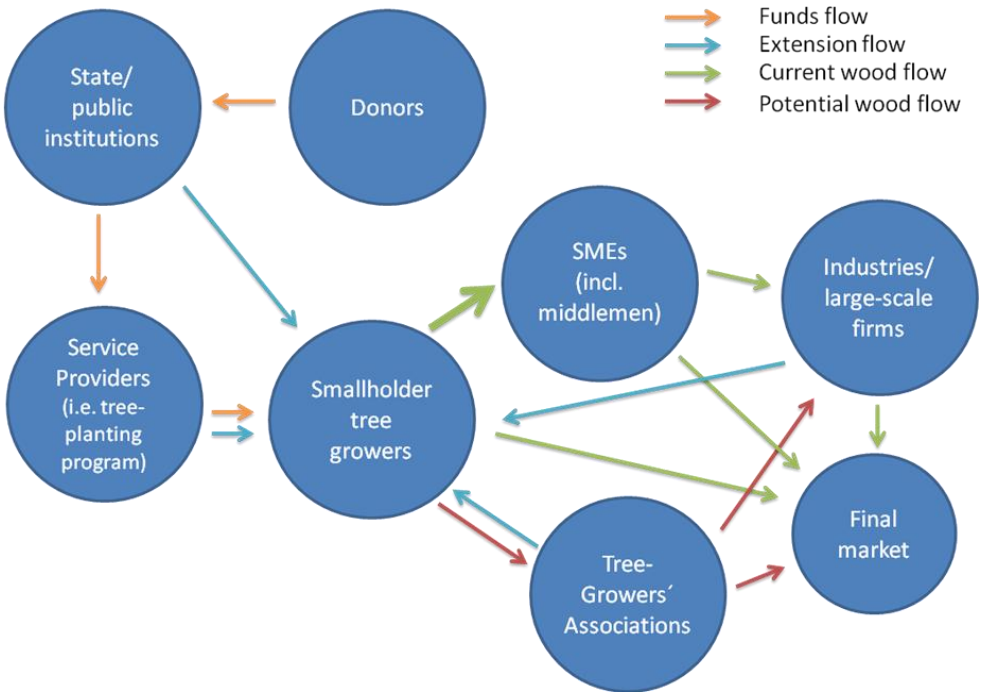

Figure 3. Stakeholders involved in the forest sector and their relations in the context of this study.

Table 1. Main interests of stakeholders and key responsibilities that should be expected in the commercial forest sector.

	Main interests	Key responsibilities
Donors	Rural development, decrease pressure on natural forests.	Provide access to finance, promote best practices (ensuring environmental and social safeguards).
State/ public institutions	Rural development, decrease pressure on natural forests, increase wood supply.	Provide adequate legal and institutional frameworks, offer adequate policy instruments, invest in infrastructure, promote best practices, and raise awareness.
Service Providers	Reputation, maximize positive outcomes.	Efficiency in project management, comprehensive support to smallholders, capacity building, raise awareness.
Smallholder tree growers	Enhance livelihoods, increase income.	Follow tree planting guidelines, commitment.
Tree-Growers´ Associations	Access to markets, long-term support to smallholders.	Technical advice, networking, addressing farmer´s concerns.
SMEs	Maximize profits, access to markets.	Entrepreneurship.
Industries/ large-scale firms	Increase wood supply, maximize profits, social acceptance.	Promote tree planting, successful business model, corporate social responsibility.
Final markets	Increase wood supply, competitive prices.	

2.2. Factors influencing farmers' silvicultural management activities

Tree management tends to be largely limited to product harvesting and communities often lack the resources to produce reliable quantities of high-quality products to meet market standards (Roshetko et al. 2007).

The general farmers' lack of knowledge and skills in silvicultural management is considered to be a major constraint to successful small-scale commercial tree planting (Byron 2001; Pattanayak et al. 2003; Cossalter and Pye-Smith 2003; Macqueen and Bolin 2018). Farmers' perceptions of the impacts of new practices on the production shortfalls, farmers' uncertainty about the innovation, and farmers' attitudes towards risk and uncertainty are important on the farmers' decision to adopt new technologies (Amacher et al. 1993; Mahapatra and Mitchell 2001). Extension and training can reduce

the uncertainty and perceived risks and thus incentivize tree planting and management (Pattanayak et al. 2003).

The individual household circumstances and external forces such as markets and policies determine the ability to adapt to new silvicultural practices over time (Mercer 2004). Farmers will invest land, labour and capital in new technologies when the expected gains from the new system are higher than the alternative systems (Mercer 2004).

Farmers with limited incomes or assets, may lack the resources (e.g.: land, capital, seedlings, tools, fertilizers, harvesting equipment) to engage in silvicultural management (Amacher et al. 1993; Pattanayak et al. 2003; Summers et al. 2004). Farmers with greater resources have lower perceived risks to engage in new technologies and are more capable to wait for the long period before harvest. Nevertheless, smaller plots can be more easily protected from fire and pests. Furthermore, having less quantity creates an incentive for the farmer to make the most out of it and thus getting more involved in the silvicultural management activities (Kallio 2013). Moreover, the type of land that the farmer owns may also be relevant, since tree cultivation often is assigned to less productive and marginal lands (Thacher et al. 1997). The availability of off-farm sources of income has also been demonstrated to influence positively the willingness of the farmers to engage in silvicultural activities (Thacher et al. 1997; Kallio 2013).

The security on land tenure is especially relevant on tree crops because of their long waiting periods before the profits can be realized. Farmers need the confidence that they will have the right to sell the planted trees in the long-term future (Byron 2001; Simmons et al. 2002; Summers et al. 2004).

The location of the tree plantation in relation to the farmer's house and to wood industries and markets, will determine the time and costs to access the woodlots for its management and the costs of transporting the raw material, thus it may influence the level of silvicultural management (Scherr 2004). Moreover, site characteristics and climatic conditions largely influence the species suitability and the management regimes.

Tree planting has been seen as a land use which requires lower inputs of labour compared to agriculture (Arnold and Dewees 2013). Labour force measured on either size of the family or, the number of adults or males in the family, has been found to have a positive influence on tree planting behaviour because once the primary labour for food production or off-farm labour has been taken care of, the extra labour can be used for secondary tasks such as tree planting (Salam et al. 2000; Pattanayak et al. 2003; Summers et al. 2004). Moreover, hired labour is important in farm-income diversification (Mahapatra and Mitchell 2001).

Age, gender and education may serve as proxy for variables difficult to measure such as farmers' preferences, risk tolerance and progressive versus traditional attitudes (Pattanayak et al. 2003). Moreover, age and education represent human capital, which may influence positively the silvicultural management due to greater environmental awareness, and enhanced knowledge of tree planting techniques and market incentives (Simmons et al. 2002).

Farmers have limited linkages to markets and information; therefore, they do not manage their woodlots because they are unsure which silvicultural activities would provide them significant profits (Roshetko et al. 2007). Apart from an attractive market available with price incentives and demand for wood-products, farmers' access to the market will ultimately determine their motivation and willingness to invest resources in silvicultural management (Byron 2001; Scherr 2004). Excessive regulations, unfair competitiveness, disregarding farmers from forest policy negotiations and lack of information about markets, which highly reflects on low negotiation power, restricts the farmers' access to markets (Scherr 2004; Perdana et al. 2012). Small volumes and lack of continuous supply from smallholder tree plantations increases harvest and logistics costs and makes farmers less attractive for the industries (Kallio 2013). However, global trends such as growing local demands, increased need for small-scale tree growing due to forest scarcity, use of marginal lands, out-grower schemes and increased awareness of the locals and the communities' role, create at the same time market opportunities for smallholders (Scherr 2004).

Assistance from either governments or external organizations in form of direct incentives such as free seedlings, cash grants or soft loans encourages farmers on tree planting activities (Thacher et al. 1997; Simmons et al. 2002). However, long-term results are uncertain and the quality of management is typically low (Thacher et al. 1997). Incentives have some serious disadvantages; unless strategically targeted, may be wasteful and have undesirable consequences (Lamb 2011).

Participation in farmers' organizations such as tree-growers' associations strongly affects the adoption of new technologies and agricultural practices (Thacher et al. 1997; Mahapatra and Mitchell 2001; Summers et al. 2004). The information and technical advice from community associations reduces the farmers' perception of risk (Lamb 2011). In regions with undeveloped market institutions, farmers' organizations can build linkages with larger buyers and overcome value chain gaps (Scherr 2004). Farmers' organizations can mobilize capital (e.g. micro-financing), undertake joint processing and management activities (e.g. site preparation, firebreaks), organize marketing deals or establish quality and conservation controls, among others. Moreover, the joint efforts of tree-growers' associations can ensure minimum supplies to large-scale buyers (Scherr 2004).

Ultimately, governments ability to create the right conditions to encourage adequate investment and market development by making clear and consistent policies and regulations, as well as providing secure land rights and infrastructure, will determine the profitability of smallholder commercial tree planting (Kallio 2013).

2.3. Species selection and description

Most of tree growers in the Southern Highlands plant trees to supply sawn timber, fuel wood, fencing poles and transmission poles (PFP 2015). Pine – and particularly *P. patula* grown for saw logs – is the most planted species (65%), followed by eucalyptus (20%). Other species planted are: black wattle (*Acacia mearnsii*), teak, cypress and others.

In the Southern Highlands of Tanzania, *Pinus patula, Pinus radiata, Eucalyptus saligna and Eucalyptus maidenii* were the most common species used by famers (PFP 2015). Currently, seedlings of *Pinus tecunumanii, Pinus maximinoi* and *Eucalyptus urograndis* (hybrid from *E. grandis* x *E. urophylla*) are being raised. These seedlings from improved sources are considered of strategic importance and will provide the basis for plus tree selection in the future (PFP 2017a).

Many pines thrive on a considerable range of site types and many are able to flourish in dry, nutrient-poor soils and degraded sites. The large number of species makes it possible to find suitable varieties for widely diverse environmental conditions. Pine logs are relatively easy to saw and most small tree growers currently favour pines over other species (Held et al. 2017). Eucalypts have not generally been grown for saw logs in the region, although recent shortage of pine in the market place has stimulated a turn to eucalypts as a source of timber. The hybrid eucalypt clones are now increasingly grown by larger companies due to their resistance to major pests and diseases and their adaptability to specific sites (Held et al. 2017). Cypress (*Cupressus lusitanica*) produces superior timber to *P. patula* but is significantly slower growing and susceptible to various pests. *Pinus* spp. may be preferred instead of eucalypts in areas where termites are abundant (Evans and Turnbull 2004).

2.3.1. Pines

The genus *Pinus* (about 120 species) are gymnosperm and monoecious. They have medium- to large-size seeds. Pines have a well-developed root system, the most important feature of which is a robust and long taproot. Many pines are tolerant of grass competition, nevertheless on sites with rapidly growing shrubs and vines, their growth will be retarded if weed control is not applied (Evans and Turnbull 2004).

South-eastern African countries rely largely on patula pine (*Pinus patula)* from Mexico (Hakkila 1994). In its native environment it is found in well-drained soils at altitudes from 1,650 to 3,000 m above sea level, with 1,000 to 2,000 mm of annual precipitation

and mean annual temperatures of 12-18ºC – absolute minimum of -10ºC (Lamprecht 1989). Its growth and wood quality is excellent when placed in suitable sites as an exotic, and it exhibits good cold tolerance and moderately drought tolerance (Hodge and Dvorak 2012). It grows up to 40 m tall and 1.2 m diameter at breast height (DBH), usually with a single, straight, slender trunk. Although it is the major commercial pine species grown in eastern Africa, in Latin America it is gradually being replaced by the faster-growing *P. tecunumanii* and *P. maximinoi*. A limiting factor for its continued broad use in South Africa is its susceptibility to a major disease caused by the pitch canker fungus (*Fusarium circinatum*) (Hodge and Dvorak 2012).

Pinus radiata is native to a very limited area of coastal California between 28º and 38ºN. In the range of its natural distribution, it is a rare and technically inferior species without commercial value (Hakkila 1994). When cultivated at suitable sites in the southern hemisphere, radiata pine grows amazingly well and has been one of the most popular exotic forest trees (Hakkila 1994). In favourable conditions it grows very rapidly during the first years (up to 1.5 m per season) (Farjon 1984). It can reach a maximum height of 40 meters; it has an exceptionally massive trunk and DBH of 1.5 m and more. Radiata pine is prone to malformation and does not shed dead branches easily. Because of its high permeability, its sapwood should be thoroughly sealed or treated with an appropriate preservative if exposed to conditions of high moisture content (Hakkila 1994). It prefers deep soils with good drainage and it is more tolerant to shade than most pines. Plantations of *P. radiata* in the tropics is concentrated at elevations between 1,500 and 3,000 above sea level, annual precipitation between 650 and 1,600 mm and mean annual temperatures of 11-18ºC (Lamprecht 1989).

P. maximinoi is one of the most common species in tropical Mesoamerica. It occurs naturally in the temperate warmer to subtropical regions from central Mexico to northern Nicaragua; between 600 and 2400 m elevation in regions with 900 to 2200 mm of annual precipitation. It has good tolerance to the pitch canker fungus but little tolerance to subfreezing temperature (Hodge and Dvorak 2012). It can grow up to 33 m high with a DBH of 90 cm or more. It has a dense rounded crown with slender horizontal branches and long internodes.

P. tecunumanii is a tropical/subtropical species that occurs in southern Mexico and throughout the highlands of Central America. It is generally found on fertile soils on mountain plateaus or valleys in areas with rainfall between 1000 and 2500 mm between elevations from 400 – 2900 m. In high-elevation populations (>1500 m) it can reach 55 m in height and more than 100 cm DBH, while in low-elevation it seldom grows larger than 30 m in height and 60 cm DBH. Several populations exhibit some degree of cold hardiness, but it has little resistance to frost when planted as an exotic (Hodge and Dvorak 2012).

The potential sites for *P. maximinoi* and *P. tecunumanii* overlap, but generally *P. maximinoi* will do better at higher altitudes and on deeper, more fertile soils than *P. tecunumanii.*

P. tecunumanii and *P. maximinoi* have shown substantially faster growth rates than improved *P. patula* in South Africa (Hodge and Dvorak 2012). In Tanzania, both species could be planted commercially in the Southern Highlands (Hodge and Dvorak 2012). However, they are shy seed producers; therefore, vegetative propagation is required to produce sufficient plants commercially. Moreover, despite its potential, they present few other challenges which require tree breeding programs to select against certain traits, avoiding non-controlled natural hybridization and careful selection of planting sites. Accordingly, *P. patula* will continue to be an important species at the Tanzanian highlands (Hodge and Dvorak 2012).

2.3.2. Eucalyptus

With very few exceptions, the genus *Eucalyptus* (approx. 700 different species) is restricted to the Australian continent and they comprise nearly all of Australia's forests. Eucalypts are angiosperm and monoecious. They are characterized by their unusual flowers, which possess neither sepals nor petals (Lamprecht 1989). Thanks to their lignotubers (and coppicing), eucalypts have a high regenerative capacity and resistance to adverse environmental conditions. The rapid growth and high biomass production rate

of many species is due to their ability to develop a large leaf area very quickly. When young, eucalypts are not at all shade-tolerant.

Eucalypts possess an extremely fast growth; on average to good sites, annual height growth is 1.5-2m, and annual increases in diameter about 1.5-2 cm (Lamprecht 1989). Eucalypts require a completely cultivated and weed-free site, often with use of fertilizer, for rapid early growth. Therefore, the need for intensive weeding is emphasized. Protection against termites is most important for eucalypts, and pests are commonly controlled by the use of pesticides (Evans and Turnbull 2004). The wood of most eucalypts is heavy and hard, and it can be used for a variety of applications.

Eucalyptus saligna can be found in elevations up to 1,200 m above sea level (Lamprecht 1989). Its natural range is characterized by heavy summer rains (800-1,500 mm) and subtropical temperatures (mean temperature of 29ºC and 4ºC in the warmest and coldest month, respectively). It thrives best in loamy to slightly clay soils, with moderate to good nutrient availability, and which have a good supply of water but are not waterlogged. It is resistant to light frosts, fairly fire-resistant and it is able to survive brief periods of drought. On medium-quality sites it can grow up to 40 m height and 50 cm DBH (Lamprecht 1989).

Eucalyptus urograndis (hybrid from *E. urophylla x E. grandis*) information is difficult to access and largely lacking in the main books about silviculture in the tropics. However, its parent *E. grandis* is normally well characterized. *E. grandis* is one of the most important plantation species of the tropics and it is often confused with its close relative *E. saligna* (Lamprecht 1989). *E. grandis* does not develop a lignotuber. It grows up to heights of 45-55 m and DHB of 120-180 cm. It has an excellent stem form. Its natural range is characterized by subtropical climate with annual rainfall of 1,000-1,750 mm (mostly during summer) and mean annual temperature between 15-21ºC (absolute minimum of -5ºC and absolute maximum of 46ºC). It grows best in deep, permanently moist well-drained loamy soils. *E. grandis* is affected by a large number of different pests and diseases (Lamprecht 1989). Thus, the hybridization with the more insect resistant *E. urophylla*, is highly beneficial.

2.4. Silvicultural management

Matching tree species with site characteristics (i.e. climate, edaphic and topographic factors) is essential; planting off-site can result in low productivity as well as susceptibility to pests and diseases. In the Highland Areas, with rainfall over 1000 mm per year, pines, eucalypts and cypresses are the recommended exotic tree species (MNRT 2017). Species diversification is emphasized but in practice, mostly monocultures are planted, considering the existing markets for the intended end products.

It is essential to choose an appropiate land-clearing method depending for each particular site to avoid harm. In cases where there are patches of natural forest remnants, these are to be left undisturbed whilst they can be planted around (PFP 2017a). Manual clearance and site preparation is widely used in the tropics. In PFP guidelines, circular weeding within 50 cm radius around the pitting spot is required (PFP 2017a). Burning has been widely used in forestry to establish tree plantations because it is cheap and quick, and it produces a layer of ash rich in nutrients temporarily (Figure 4). However, past experiences have shown its likely negative results. To name few, burning large areas produces atmospheric pollution, high intensity burns may result in greater nutrient losses (e.g.: by volatilization, leaching and erosion) and subsequent depressed growth.

Figure 4. Planting area recently cleared by fire, a common practice during site preparation.

Furthermore, especially in areas with high risk of fire, the risk of fire getting out of control is likely to happen (Evans and Turnbull 2004).

Planting season is during the rainy season (end of December until March approximately), theoretically when the soil moisture depth is of 15-30 cm or 100 mm of steady rain has fallen. Planting should be done as soon as possible so that seedlings can establish a deep root system before the onset of dry season. According to PFP guidelines, planting must be done before the end of February (PFP 2017a).

Most industrial plantations are planted at spacing of 2.5-3.0 m (1100-1600 stems ha^{-1}). Stockings at plantings of less than 900 ha^{-1} for pines would be inadequate for proper plantation development (Evans and Turnbull 2004). For saw logs, wider spacing is required than for pulp. PFP guidelines required a spacing of 3x3 m but slope correction on planting density should be applied on steep sites (>20% slope). With such spacing, only up to 10% mortality is acceptable (Evans and Turnbull 2004); however, PFP guidelines established a minimum of 80% survival (PFP 2017a). Pitting should be of 20-30 cm deep x 20-30 cm diameter (MNRT 2017). If mortality is too high, blanking or in-filling must be applied within few weeks for the fast-growing broadleaved species (i.e. eucalypts) and within few months (1 month according to PFP guidelines) for other species. Seedlings used for blanking should be healthy, robust, and a little larger than average with good root development. Fertilizer should be applied for eucalypts right after planting; 30 grams per seedling (PFP 2017a).

Rotation ages are not yet well determined in Tanzania, and it is currently under review; pine and eucalypts rotation for saw logs is about 25-30 years and eucalypts for transmission poles about 10 years (MNRT 2017).

Control of competing weeds is an important part of plantation establishment as well as during the first years until trees are growing well and its size enables them to suppress competing weeds (Evans and Turnbull 2004). The intensity of weed control varies according to species, site and climate. For tropical pines the period for weeding is typically 1-3 years; moreover, it becomes essential only when weeds grow more than

50% taller than the tree. Weed control is also important for fire prevention. Similarly to PFP guidelines, the Kenyan Forest Department's Technical Order (1996) states that weeding should start soon after planting and continue for 2-3 years depending on species and site, a minimum thorough weeding once a year and preferably done soon after planting and at start of the dry season. Manual weeding on the Southern Highlands consists on hoeing of 1 m diameter around each tree (often called circle weeding, Figure 5) and slashing the vegetation (often called slash weeding, Figure 6) (Evans and Turnbull 2004; PFP 2017a). In general, the greater the area weeded, the less competition and thus better tree survival and growth. Steep, erodible slopes should not be clean weeded, but instead slashing may be applied. Within 20 cm from the tree, weeds should be hand pulled to minimize damage to surface roots (MNRT 2017).

Figure 5. Two-year-old woodlot of *Pinus patula*. Circle weeding applied up to the standards.

Figure 6. One-year-old woodlot. Smallholder in the process of slash weeding.

Intercropping with tree seedlings (e.g. Taungya system) enables weeding of trees when food crops are harvested (Figure 7), but crops like maize may delay early growth due to shading of tree seedlings. Poor supervision of agroforestry systems may lead to over hoeing and tree root damage. To minimize such negative impacts, Taungya should only be allowed for one cropping season (MNRT 2017).

Figure 7. Two-year-old woodlot of *Pinus maximinoi*. Agroforestry system with Irish potatoes.

Pruning is mainly carried out in tropical tree plantations to improve stem and wood quality in industrial crops (Evans and Turnbull 2004). Moreover, pruning may be practiced to obtain fuelwood. Pines such as patula pine have persistent branches and must be pruned if knot-free timber is desired; however, most eucalypts are good natural pruners and rarely need artificial pruning (Evans and Turnbull 2004). Pruning is only required if high-grade timber is required, for instance in veneer, plywood, high-grade constructional timber or transmission poles production. Nevertheless, low pruning, which means removing branches up to 2 m height up the stem, is also done to improve access, reduce fire hazard or facilitate thinning operations (Evans and Turnbull 2004). If knot-free timber can only be achieved by pruning, pruning is only advised if markets offer higher price for the timber of higher quality. Pruning is expensive and unfortunately there is often much doubt whether the investment made is rewarded with a better market price (Evans and Turnbull 2004). Timing and intensity of pruning needs to be balanced between: (1) maximizing the knot-free core and (2) minimizing the loss of growth due reduction of photosynthetic area. The typical pruning schedule for most coniferous species in the tropics in order to produce 10 m clear stem is done in 4 pruning operations (Table 2).

Table 2. Typical pruning schedule for most coniferous species in the tropics.

Pruning operation	Pruned height (m)	Approximate timing	
		Stand height (m)	Stand condition
First	2.5	6.0	Just after canopy closure
Second	5.0	9.0	Prior to first thinning
Third	7.5	12.0	At time of first thinning
Fourth	10.0	15.0	Prior to second thinning

Source: Evans and Turnbull 2004

Dead branches should be also be pruned to avoid loose knots. Branches should be flush cut with the trunk using a sharp curved pruning saw aiming to minimize bark damage (MNRT 2017). Where possible, pruning should coincide with thinning so that the pruned trees respond to thinning and thus compensate for possible loss in growth due to pruning. Pruning will vary with species, sites and growth rates. The pruning schedule for *Pinus patula* in Tanzanian state-owned plantations is 3 times at 3, 5 and 7 year-old plantations in best sites and 2 times at 7 and 9 year-old plantations in worst sites (MNRT 2017). Pruning schedule for pines in private enterprises in Southern Highlands is 3 times at 4, 6-7 and 8-10 year-old plantations (dominant heights of 4.5, 8 and 11 m, respectively) in Green Resources Ltd or 4 times at 3-4, 5-6, 7-8 and 9-10 year-old plantations (mean dominant height of 4, 7.5, 10.5, 13.5 m, respectively) in Tanganyika Wattle Company.

Artificial thinning is the operation that reduces the number of trees growing in a stand before clear felling. It is normally carried out several times during a rotation and starts few years after canopy closure (Evans and Turnbull 2004). Thinning a stand reduces the number of trees competing for light, nutrients and soil moisture; which lowers the natural mortality and favors greater and deeper crowns on remaining trees. The main effect of thinning is greater diameter growth on remaining trees; little effect on height growth has been observed (Evans and Turnbull 2004). Thinning is also applied to remove dead, dying or diseased trees, which may be source of infection and cause damage to the remaining healthy trees. Removing poor quality trees (bended, forked, swept, roughly branched), ensures that future growth is concentrated only on the most

vigorous and quality trees. Moreover, thinning provides some financial returns before final harvest from selling the thinned trees usually from second thinning onwards.

Compared with information about afforestation techniques, the effects of thinning and its most suitable regimes in the tropics are less known. Countries like Tanzania have adapted the South African thinning practices. The woodlot technical guidelines of Tanzania (MNRT 2017) recommend selective thinning (i.e. individual tree selection) and consider the thinning regimes used in public and private sector (Table 3) appropriate.

Table 3. Thinning regimes in public and private sector in Tanzania. Source: MNRT, 2017.

Plantation owner	Species	Age (years)	Stems per hectare
State	*P. caribaea, P. ellioti, P. patula, P. tecunumanii, C. lusitanica*	0	1111
		10	650
		15	400
		25-30	0
Green Resources Ltd.	*P. patula*	0	1600
		10	800
		14	500
		18	300
		25	0
Tanganyika Wattle Company	*P. patula, P. elliottii, P. radiata*	0	1111
		4	800
		12-13	400-500
		20-23	0

Protection against risk (e.g. pest, diseases, fire, etc.) is an essential part of silviculture. Good silviculture – i.e. site-species matching, genetically diverse, robust and healthy planting material, early blanking, proper weeding, optimum stocking (incl. timely thinnings) and tree species diversity – will reduce stress and promote healthy trees less susceptible to pests and diseases (MNRT 2017). The usage of improved tree seedlings – provenances or hybrid material with genetic traits tolerant to organic damage – can also considerably reduce the risk of pest and disease outbreaks. Effective monitoring is

highly recommended for early detection of damages and early action before it spreads to uncontrollable levels. In Tanzania the lack of capacity to monitor forest health is limiting the information on species and areas affected by pests and diseases (MNRT 2017).

Fire is considered the most important risk in young tree plantations (i.e. before canopy closure) in Tanzania (MNRT 2017). External firebreaks (Figure 8) of minimum of 10 m surrounding a block of tree plantations (about 30 ha) is recommended (MNRT 2017). The width will depend on the level of risk. Internal firebreaks should have a width of 5 to 10 m depending on the slope. Firebreaks should be maintained before dry season. It can be done by manual clearance, ploughing with a tractor or controlled burning if surrounding vegetation is green or with previous preparation of cleared strips on both sides of the firebreak. In older plantations, combustible material on the forest floor should be reduced through prescribed burning, grazing or clean weeding (MNRT 2017). In PFP guidelines, firebreaks should be minimum 20 m and completed by 31st July and a fire patrol should be arranged from August 1st until November 30th. Moreover, there should be firefighting equipment available, access to water and a fire management plan.

Figure 8. Firebreaks surrounding smallholder tree plantations in the southern highlands of Tanzania.

3. MATERIALS AND METHODS

3.1. Research area

This study was carried out in the Southern Highlands of Tanzania. The most recent estimation of tree planting area in the Southern Highlands is 207 000 ha, of which 64% belongs to smallholder plantations (Mankinen et al. 2016).

Inside the Southern Highlands, the study took place mainly on the Njombe region (Figure 9), which has the lowest population growth rate of the country, 0.8 per cent (National Bureau of Statistics 2012). It is a rather sparsely populated area with 70% of the population living in rural areas. Sex ratio is 88 males per 100 females. Njombe region has altitudes from 1 300 to 2 500 meters above the sea level, mean annual rainfall is 1 140 mm and mean annual temperature is 16.4ºC (Climate Data 2018).

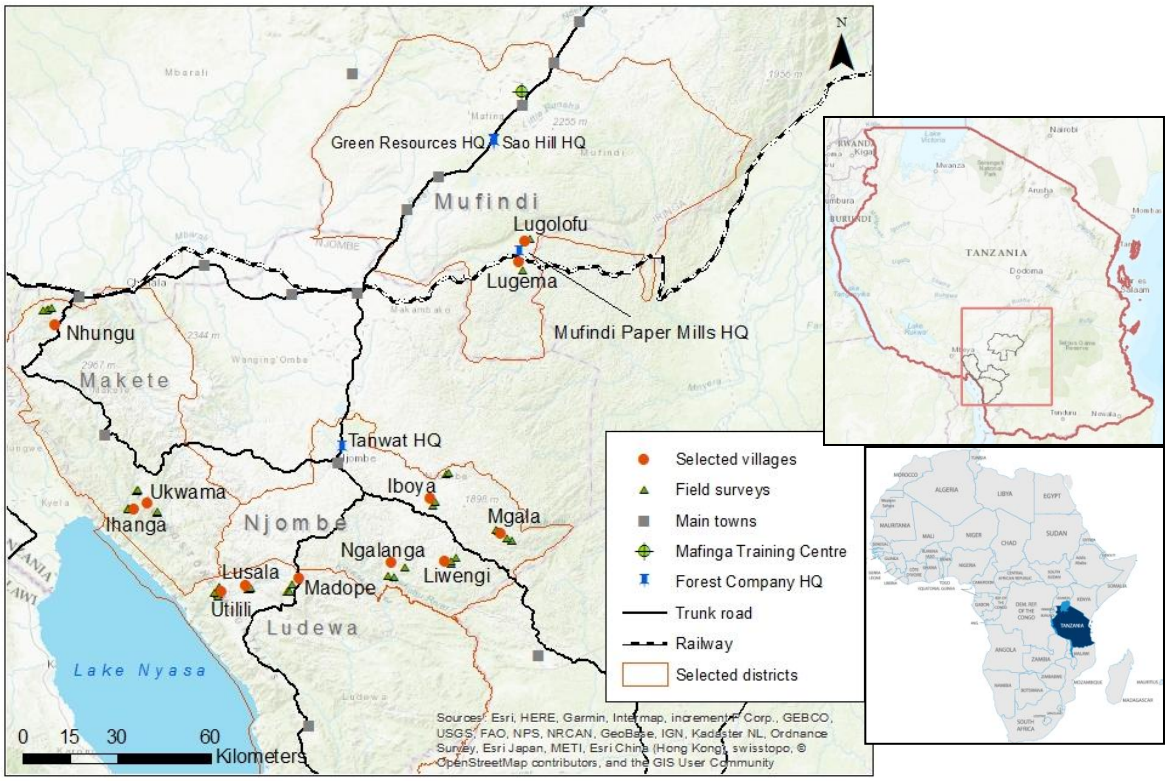

Figure 9. Map of the area where the research was carried out.

3.2. Sampling

The study took place in the districts of Ludewa, Makete, Njombe and Mufindi. These districts cover well the area of the Southern Highlands and they have been targeted by the state and donors to promote commercial tree planting among smallholders.

For this study, 12 villages were selected. Selection was aimed to cover variability together with convenient logistics. Variability between villages included: remoteness versus good access to roads and markets, long versus short history in tree planting, and level of support received in tree planting (Table 4). All tree growers from the villages were encouraged to participate in the interview and informed about the study via tree-growers' association. They were given two different days to participate. From the tree growers present and willing to participate, interviewees were selected.

The level of support received in tree planting was measured through: number of projects providing extension and number of direct incentives. Extension is understood as the dissemination of information and technology necessary for tree planting (incl. tree seedlings, fertilizers, training, technical advice, etc). For this study the most relevant extension was given by PFP to all villages. Second most important was extension by Green Resources Ltd. in Lugema village. Lusala, Ihanga and Ukwama mentioned some extension by another program or company, not specified. Finally, most of the villages reported some kind of extension by the government officials.

Direct incentives in this study include: tree seedlings, fertilizers, herbicides, insecticides and cash incentives. Tree seedlings came mainly from PFP, except for Utilili, Lugema and Lugolofu, which reported tree seedlings from another project. Cash incentives are cash grants given to farmers as a reward for carrying out proper weeding in their woodlots.

Liwengi village has been considered as the control village for this study since it was the only village without direct incentives. Lusala and Mgala were the only villages where cash incentive for weeding was present. In Mufindi district there is the remarkable presence of a major paper industry, Mufindi Paper Mills Ltd.

Table 4. Main characteristics of the villages selected for the study.

District and village	Distance to main trunk road (km)	Distance to main town (km)	Average years tree planting	Nº of projects providing extension	Number of direct incentives	Others
Ludewa						
Lusala	15	97	18	3	4	Cash incentive
Madope	0	57	13	2	3	
Utilili	20	102	14	2	4	
Makete						
Ihanga	100	45	14	2	1	
Nhungu	15	15	15	2	1	
Ukwama	75	40	12	3	1	
Mufindi						
Lugema	85	85	6	2	4	Major paper industry
Lugolofu	75	75	10	2	3	
Njombe						
Iboya	7	44	18	1	3	
Liwengi	10	65	16	2	0	
Mgala	22	73	11	2	2	Cash incentive
Ngalanga	25	62	18	2	2	

3.3. Data collection

For each village, a preliminary presentation of the aim of this study was presented to all tree growers who were previously informed via extension officers (Figure 10). Information about the study was provided to all tree growers, who were present, from the village. Afterwards, tree growers expressed their voluntary interest to participate in the study and agreed to be available for the interview. Moreover, every farmer was given the choice to accompany us to the later field surveys for cross-checking the information given during the interviews. The cross-checking of the interviews was carried out with 44 field surveys to woodlots. All woodlots surveyed belonged to different farmers.

The data consists of 114 semi-structured questionnaires at household level. The questionnaire was firstly tested with the first 2 villages, Lugema and Lugolofu, and slightly modified afterwards to match the needs of the study. Input from local experts was highly useful to the final layout of the questionnaire. Furthermore, the questionnaire

was carefully translated to Kiswahili. The interviews were conducted at the village office by the researcher itself together with a translator, which had experience working in tree planting issues in the same area of the study. The first section of the questionnaire consisted of questions related to socio-economic information, such as age, gender, education, sources of income, household size, land ownership and land use rights, participation in farmers' groups, etcetera. The second section was related to woodlot management, covering both the characteristics of the woodlots and the reported management activities applied. The management activities include: site preparation and establishment, weeding, firebreaks, pruning, thinning and final harvest. Moreover, data about the supports and extension received on tree planting activities was recorded. Finally information about the rationale behind woodlot management was gathered on the third section of the questionnaire. This last section was divided for each of the different management activities and it included both open-ended questions and pre-established statements to which farmers had to agree, disagree or express their lack of knowledge. The full questionnaire can be found in Annex 2.

Figure 10. Presentation of the study to the tree growers in the village of Nhungu.

The field survey consisted of (1) a general characterization with data such as location, slope, species, area and site description, (2) plot measurements such as survival rate, spacing, height and DBH, and (3) woodlot observations related to presence of damages and presence of management activities applied (Figure 11).

Figure 11. Field survey team and extension officer measuring survival rate and spacing.

3.4. Data analysis

3.4.1. Methods used to enter and analyse the data

In order to sort and input the information gathered from the questionnaires, a qualitative content analysis (QCA) was applied. QCA is a method for describing systematically the meaning of qualitative material and it is done by classifying data as instances of the categories of a coding frame (Schreier 2012). QCA is a suitable method for describing material which requires some degree of interpretation. Following the principles of QCA explained by Schreier, the coding frame established follows the requirements of unidimensionality, mutual exclusiveness, exhaustiveness and saturation. The categories and subcategories of the coding frame were guided by the research questions of the study. The main topics are based on the literature review of previous studies. The final structure of the coding frame was created in a data-driven way, by letting the categories

emerge from the material. When building the coding frame, everyday knowledge acquired on the field and logic were also applied. At first, large amount of categories were added to the point of saturation. Afterwards, relevant categories were kept while irrelevant ones were assigned to a residual category at each level of the coding frame.

Descriptive statistics, cross-tabulations, Chi-square test, Mann-Whitney U test and Spearman's rank correlations were used to study the relationships between (a) socio-economic factors, rationale and external support, and (b) farmers' tree-planting activity.

3.4.2. Description of the indicators used to analyse the data

First of all, to have a more comprehensive variable to measure the level of the silvicultural activities applied; four indicators were created from the data that was originally collected:

(1) **Level of silvicultural management**. Measured from 0 to 10. The punctuation goes as follows:

- Land preparation taking into account the previous land uses:
    - Just pitting or clear only the line to plant: *0 points.*
    - (1) Pitting *and* (2) clear/slash the whole vegetation *or* clear by fire *or* application of herbicides o*r* former land use was agriculture and the tree plantation was established right after harvest: *1 point.*
- Blanking:
    - Blanking not applied: *0 points.*
    - Blanking applied: *1 point.*
- Circle weeding applied to young woodlots of 0, 1 or 2 years old, after site establishment:
    - No weeding applied at all: *0 points.*
    - Weeding applied only 1 season from the last 2 seasons: *1 point.*
    - Weeding applied the last two seasons: *2 points.*
- Slash weeding applied to young woodlots of 0, 1 or 2 years old, after site establishment:
    - No weeding applied at all: *0 points.*
    - Weeding applied only 1 season from the last 2 seasons: *1 point.*
    - Weeding applied the last two seasons: *2 points.*
- Pruning of pines applied or planning to apply it:

    - Pruning neither applied nor planning to: *0 points.*
    - Pruning applied or planning to: *1 point.*
- Thinning applied or planning to apply it:
    - Thinning neither applied nor planning to: *0 points*.
    - Thinning applied or planning to: *1 point*.
- Firebreaks:
    - No firebreaks or applied once in the past but did not maintain: *0 points.*
    - Building of firebreaks to some of the farmer's woodlots: *1 point*.
    - Building of firebreaks to all the farmer's woodlots: *2 points.*

(2) **Level of circle weeding**. Applied to young woodlots of 0, 1 or 2 years old after site establishment. Measured from 0 to 4. The punctuation goes as follows:

- No weeding applied: 0 points.
- Weeding applied only 1 season from the last 2 seasons to some woodlots: *1 point.*
- Weeding applied only 1 season from the last 2 seasons to all woodlots: *2 points.*
- Weeding applied the last two seasons to some of the woodlots: *3 points.*
- Weeding applied the last two seasons to all the woodlots: *4 points.*

(3) **Level of slash weeding**. Applied to young woodlots of 0, 1 or 2 years old after site establishment. Measured from 0 to 4 following the same punctuation as for circle weeding.

(4) **Level of firebreaks**. Measured from 0 to 3. The punctuation goes as follows:

- No firebreaks applied ever: *0 points.*
- Firebreaks applied once in the past but did not maintain them last year: *1 point.*
- Firebreaks applied and maintained in some of the farmer's woodlots: *2 points.*
- Firebreaks applied and maintained in all the farmer's woodlots: *3 points.*

Secondly, a large number of variables linked to rationale for silvicultural management were directly collected during the interviews. In the section 4.3, all these factors are described separately. However, in the section 4.4, to facilitate the analysis when looking for relationships between variables, some of these factors were put together. Three new variables were formed: (1) very positive attitude towards weeding, (2) skeptic attitude towards weeding depending on conditions and, (3) very positive attitude towards firebreaks.

Positive attitude towards weeding is measured by the recognition of all the benefits from weeding which were mentioned by the interviewer. There were six benefits included in the pre-established statements included in the questionnaire: (1) better growth, (2) faster growth, (3) prevent fire hazard, (4) enhance woodlot accessibility, (5) increase seedling survival, and (6) nutrient optimization. Therefore, the farmers which were classified as having very positive attitude towards weeding are those who acknowledged all the previously mentioned benefits. Farmers which are considered to have a skeptic attitude towards weeding are those who mentioned some reason to not apply weeding.

Likewise, farmers which are considered to have a very positive attitude towards firebreaks are those who did not find any reasons to not build firebreaks.

3.5. Validity of the data and methods

The sampling size as a whole is well representative of the study area. For all the villages there is a sufficient amount of interviews to characterize tree planting activity and rationale. However, for the first 2 testing villages, Lugema and Lugolofu, the sampling size was limited and therefore, results from these villages should be carefully analyzed and generalizations should be avoided.

On the one hand, nearly 40% of the farmers interviewed were cross-checked on the field, thus providing a solid reliability of the results. On the other hand, farmers had on average 6 woodlots per household, thus roughly 7% of the woodlots were cross-checked on the field. Even though the difference between these two numbers is considerable, still provides reliable findings which can be extended to at least some degree over the region. One could argue if it would have been more beneficial to reduce the amount of farmers cross-checked in exchange of cross-checking all woodlots from one single farmer. Nevertheless, such an approach would have been in most of the cases unfeasible, since most of the tree growers have their woodlots dispersed over large areas of the territory and usually only accessible on foot.

4. RESULTS

4.1. Characterization of tree plantations in the study area

Most of the farmers (29%) decided to engage in tree planting activities after seeing how relatives, friends or neighbours obtained profits from timber sales after harvest. Others (22%) saw their plantations as an investment for the future, comparable to a saving account that could be used if needed. Other reasons to start tree planting were: to increase income, because the school, relatives or government motivated them, after receiving tree-planting extension or to collect firewood. Nearly all farmers indicated commercial timber production as the main purpose of their plantations. Other purposes of the tree plantations were: own use for construction, firewood and charcoal.

On average, farmers had 6 woodlots, but as many as 28 woodlots per household were recorded. Tree planting area per household was 6.6 hectares on average but there was large differences; minimum of 0.2 ha and maximum of 230 ha was estimated. Nearly all respondents had planted during the last season. On average the oldest plantations were 10 years old, except for the village of Lusala with an average of 17-year-old plantations. Pine was the most planted species by large (63%), followed by eucalyptus (30%) and a minor amount of cypress (3%) and wattle (4%).

About a quarter of the farmers applied agroforestry in their woodlots, but there were great variations between villages. The vast majority of crop species grown between the rows of trees were legumes and maize, both applied in equal amounts.

In most of the cases woodlots were established on agricultural land (45%). Furthermore, farmers mentioned that native woodlands (20%) were converted to tree plantations, as well as fallow lands (18%), pasture lands (15%) and minor proportion of native grasslands (2%).

Fire was the main damage that woodlots experienced in the past (47% of the farmers). Other damages to woodlots included cattle trampling, drought and light insect damage. One third of the farmers reported that their woodlots had not been affected by any damage.

Almost 40% of the woodlots were planted with seedlings provided by PFP. Half of the farmers interviewed obtained the tree seedlings from local nurseries, the other half from PFP and a few were bought from major commercial nurseries. Only eleven respondents grew the tree seedlings by themselves from seeds they either picked from other woodlots or bought.

4.2. Current silvicultural practices applied by tree growers

Household members were the main workforce for most of the silvicultural activities (Figure 12). Except in some villages where paid labour and TGA cooperation dominated. The construction of firebreaks was mainly done via TGA cooperation (building of a firebreak surrounding a block of woodlots planted in communal lands).

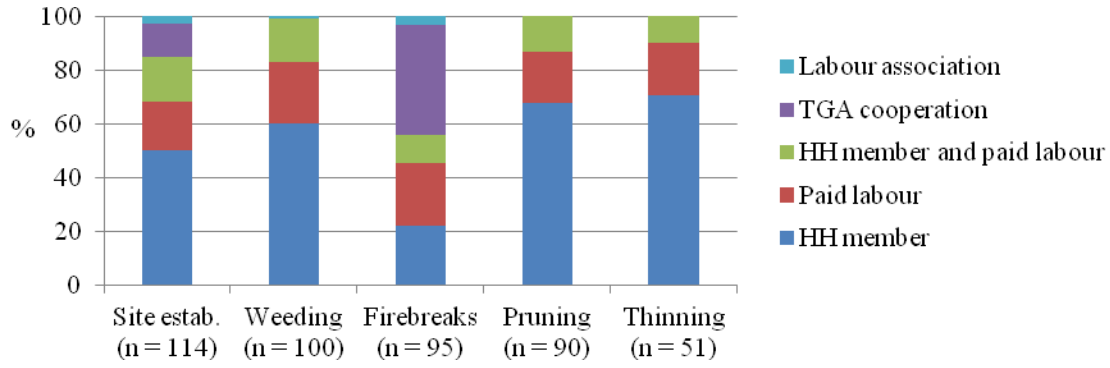

Figure 12. Types of workforce carrying out different silvicultural activities.

The majority of the tree growers had applied silvicultural activities because they were instructed to do so, except for pruning, which most of the farmers applied based on their own experience (Figure 13). Certain groups such as males, 18 to 24-year-old farmers, farmers older than 55 and higher-educated farmers managed their woodlots based on their own experiences relatively more than women, middle-age farmers or lower-educated farmers.

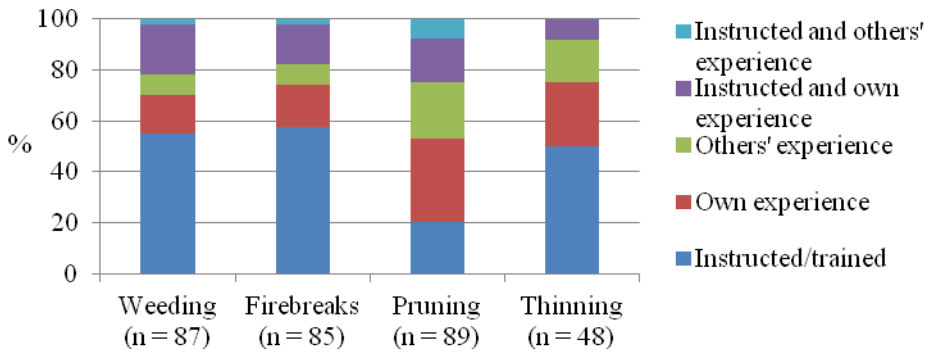

Figure 13. Percentage of farmers that applied different silvicultural activities based on their own experience, based on other tree-growers' experience or because they were instructed by experts.

Technical advice about silvicultural management came either from forestry program present in the study area via village-based extension officers, from government officials or through the tree-growers' association. According to farmers, PFP's extension focused mainly on site preparation, weeding and firebreaks.

In Annex 1 there are the detailed results from the activities related to woodlot management and the frequencies of farmers applying them. An overview of the activities during silvicultural management is provided below. Because of the wide scope of the Private Forestry Programme in the region, and the likely influence that this tree-planting program has had on the farmers' silvicultural management, in the cases where relevant, results are divided by (1) cases where farmers received the external support from a major forestry program and (2) cases where farmers did not received this support. This external support refers to all direct and indirect incentives provided by tree-planting programs, but some of the farmers without the support may have also received extension or at least some kind of technical advice. Moreover, all farmers with external support belong to a well established and functioning TGA, while farmers without the support do not.

Site preparation and establishment: Tree growers applied substantially more activities during site preparation after the arrival of incentives and extension in the region (Fig. 14); bigger proportion of farmers slashed the vegetation and cleared the plot by fire. Clearing by fire was reported both with and without the protection with firebreaks.

Circle weeding during site establishment also increased after the program arrived in the region, and removal of native trees had slightly increased.

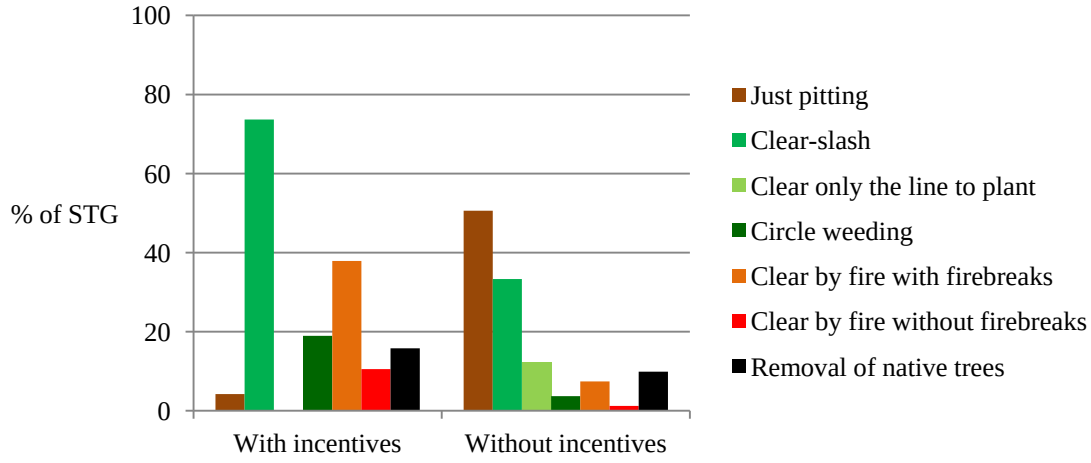

Figure 14. Percentage of tree growers who applied different treatments during site establishment. Farmers could choose more than one option, except for the category of "just pitting". The results are divided by cases in which farmers received support (n = 95) and cases in which farmers did not receive the support from the program (n = 81). Samples are dependent for this particular data.

Lining was applied by nearly all farmers. Blanking was practiced by a large majority of the farmers (81%). Only 20% of the farmers who had planted eucalyptus applied fertilizers, which were provided by the tree-planting programme. Farmers receiving incentives had larger average pit size (30.6 cm, n=92) than farmers not receiving them (20.5 cm, n=22). Plantations were planted with spacing between 2.5 m x 2.5 m and 3 m x 3 m on average; but before receiving any extension, trees were planted with closer- and more irregular spacing (2.54 ± 0.95) than after receiving incentives (2.85 ± 0.58).

Circle weeding: For many of the farmers, circle weeding was introduced for the first time by the extension from the tree-planting program. Participants without external support reported more frequently to not apply circle weeding compared those with the support (Figure 15). Even when circle weeding was applied, more than half of the members did not weed all the required young woodlots and not every season.

Slash weeding: On the contrary, slash weeding was proportionately more applied by farmers without external support (Figure 15). Similarly to circle weeding, even when

applied, it was not done every season, and not to all the young woodlots. However, slash weeding was generally applied more frequently than circle weeding, and more frequently in the last two seasons.

Very few farmers mentioned weeding twice in one season. The timing of weeding was largely depending on the timing of other labour-intensive income activities. During late June, the start of dry season, many of the farmers did not yet complete the weeding activities.

Firebreaks: Application of firebreaks was a commonly reported activity; 73% of STGs

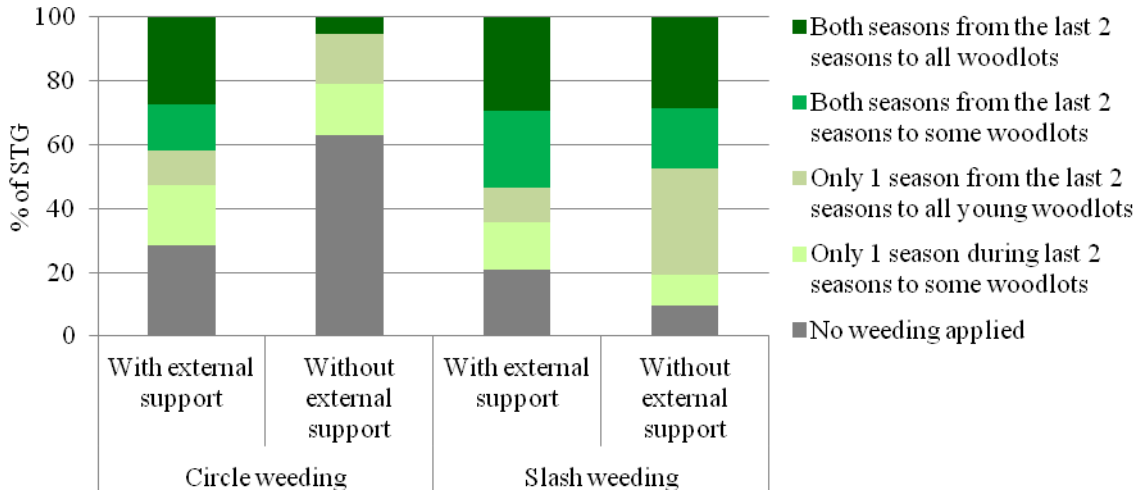

Figure 15. Percentage of farmers who applied circle and slash weeding to young woodlots. Different levels of weeding depend on whether all young woodlots were weeded and whether it was weeded in the last 2 seasons. Data from circle weeding with (n = 91) and without the support (*n* = 19); and, from slash weeding with (*n* = 92) and without the support (*n* = 21).

applied firebreaks around their woodlots and they maintained them at least during the last year (Figure 16). But even when firebreaks were applied and kept, relatively low proportion (25%) of farmers did it to all woodlots. Participants receiving external support build significantly more firebreaks. Firebreak width was on average 6.7 m, minimum of 1.5 m and maximum of 20 m. Farmers receiving external support had on average greater widths (7 m) than those without the support (5.1 m).

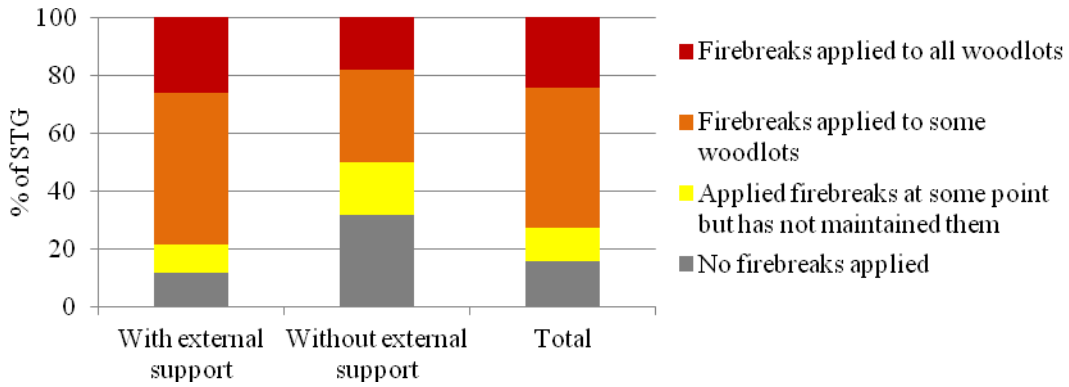

Figure 16. Percentage of farmers who built firebreaks. Data from farmers with support (n = 92) and without (n = 22).

Other methods for reducing fire hazard: Few farmers indicated activities such as weeding and planting crops on the woodlot surroundings, in order to reduce fire hazard. Moreover, some of the tree growers indicated recurrent surveillance of the woodlots, so in the case that fire would start it could be extinguished.

Pruning: All farmers already applied pruning or were planning to apply it. It is worth to mention that 10% of STGs who had woodlots older than 4 years old, did not yet apply pruning. For farmers who already applied pruning, on average they pruned for the first time when the plantation was 4 years old and pruned 2.5 times per rotation. Even though it was not further analysed during the interview, field observations confirmed that some farmers pruned PFP-woodlots (i.e. woodlots planted with seedlings provided by PFP) at a young age, but not yet pruned the older woodlots.

Thinning: Relatively high number of farmers (33%) neither applied thinning nor was planning to do so. The tree-planting program did not yet have any influence on this activity. From the 52 respondents who already thinned their plantations, on average the first thinning was done in 4.2-year-old woodlots and woodlots were thinned 1.6 times per rotation, but 3 and 4 times per rotation was also reported.

Rotation age: Forty percent of the STGs already applied final felling of their woodlots. On average, pine was harvested from 12 to 14-year-old woodlots and eucalyptus from 11 to 13-year-old woodlots (Table 5). However, rotation ages varied from 7 to 24 years

for pine and from 6 to 25 years for eucalyptus. From the tree growers who did not yet apply final harvest, 23% lacked the knowledge about the rotation age, and the rest estimated the rotation ages (Table 5). No significant differences were found between tree growers with or without external support.

Table 5. Average earliest and latest rotation ages for each species.

Age of final cut (years old)				
	Pine	Eucalyptus	Cypress	Wattle
Applied	*n* = 43	*n* = 25	*n* = 3	*n* = 3
Average earliest	12.3	11.8	14	7.7
Average latest	14	13.4		
Estimated	*n* = 47	*n* = 10		
Average earliest	12.9	8.2		
Average latest	13.3	9.2		

Markets: Most commonly STGs who did the final harvest sold standing trees to middlemen, either single trees or the whole woodlot (Table 6). Few STGs harvested and made timber themselves and sold it to middlemen. Other roundwood buyers were: local government, other SMEs or final users. Some harvested for own use as well. The majority of STGs forecasted to sell the final harvests to middlemen (Table 6). However, some farmers were expecting PFP to find new buyers or planning to sell the trees through the TGA as a group. Other predicted markets mentioned were: SMEs, selling in the village market or selling the timber.

Table 6. Frequencies of market options for already sold trees and market prediction.

Buyers	
For already sold trees (*n* = 46)	% of STGs
Sold standing trees to middlemen	80
Made timber and sold to middlemen	9
Others	11
Prediction (*n* = 69)	
Sell to middlemen	32
Expecting PFP to find the market	14
Sell through TGA, as a group	7
Others	20
Do not know about the market	26

4.3. Farmer's perceptions and rationale behind silvicultural activities

General rationale: Almost half of the tree growers (48%) believed that having a limited and pre-established stand tree density is beneficial. The rest considered that it is beneficial to plant as many trees per hectare as possible (41%) or they did not know about stand tree density (11%). More than half (58%) recognized the benefits of waiting to harvest until trees have a good diameter, so that it is more profitable to have fewer trees but bigger. The rest of the farmers preferred to harvest earlier and/or to have more but smaller trees.

Practically all farmers (96%) acknowledged the existence of price premium for straight and knotless logs and 90% of the farmers recognized the enhanced performance of seedlings from improved seeds which often come from major tree nurseries.

Surprisingly almost all farmers (96%) felt secure with the land tenure of their woodlots even though only 8% had an actual formal title for the ownership of their woodlots.

Nearly all farmers (94%) believed their woodlots were generally in good condition and grew well but they could grow even better if the farmers would get further extension.

The three most typical barriers identified to increase woodlot management and thus enhance woodlot performance are: time, money and distance (Figure 17). The lack of time and money appeared to be more problematic than the distance to the woodlots.

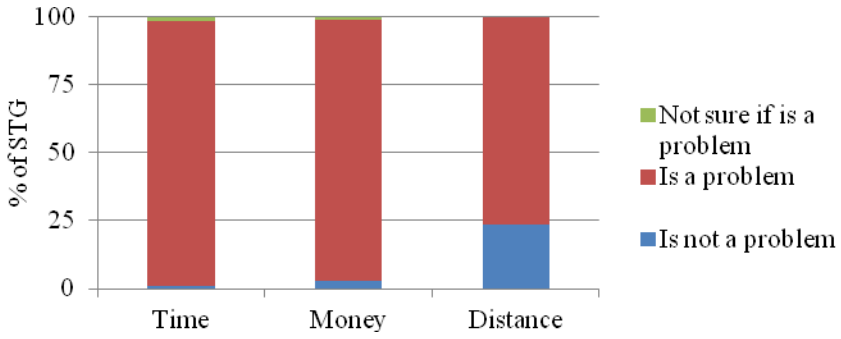

Figure 17. Percentage of farmers (*n* = 114) which consider time, money or distance as barriers to enhance woodlot performance.

Many farmers considered the weeding activity to be too expensive and time consuming compared to the benefits, while the majority of the farmers considered pruning and thinning activities neither too time-consuming nor expensive compared to the benefits (Figure 18).

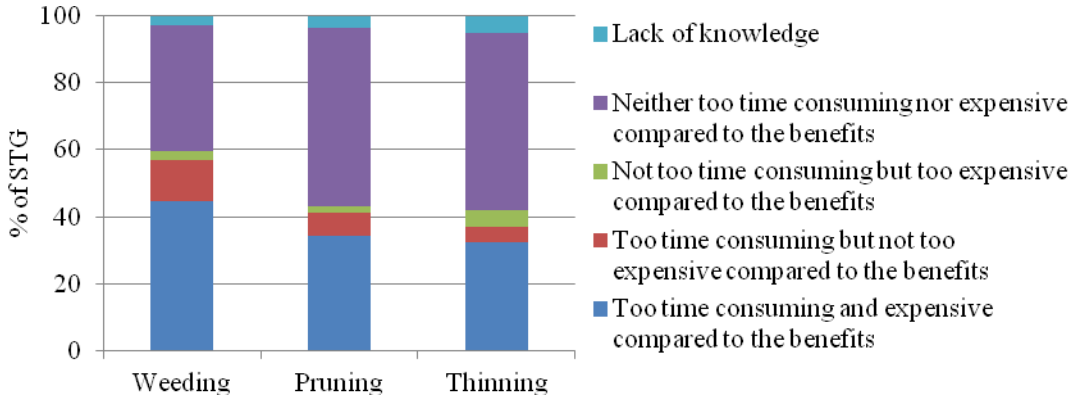

Figure 18. Farmer's perception concerning the benefits of weeding, pruning and thinning compared to the time consumed and money spent while applying these activities.

Site preparation and establishment rationale: More than half of the farmers (57%) did not acknowledge the importance of pit size for the proper performance of the seedling. Nevertheless, nearly all farmers (96%) acknowledged the importance of proper slashing during site preparation to improve the performance of the tree seedlings.

Weeding rationale: The various reasons to weed or not to weed were gathered during the questionnaire with both open-ended questions and pre-established statements that farmers were asked to agree, disagree or give an "I don't know" answer (Tables 7 and 8). Within the statements, the following benefits were included: woodlot accessibility, better growth, faster growth, nutrient optimization, increased survival and decreased fire hazard. Therefore, all these benefits have the highest rates of response. However, many of these benefits were also mentioned by the farmers previously on the open-ended question. In the same manner, the reasons to not apply weeding included on the pre-established statements were: increased survival and drying of the soil; thus, they had as well the highest response rates.

It is important to consider this previous information when analyzing the results. This combination of open-ended questions and statements gave us the chance to analyze farmer's rationale and to identify what farmers perceive as negative and positive about weeding.

Table 7. Benefits of weeding perceived by tree growers. Percentage of smallholder tree growers who chose that specific answer and percentage of responses from the total amount of answers.

Weeding benefits	% of responses, (n = 692)	% of STGs (n = 114)
Better growth	16.0	97
Faster growth	15.8	96
Prevent fire hazard	15.8	96
Enhance woodlot accessibility	15.8	96
Increase seedling survival	14.2	86
Nutrient optimization	12.0	73
To look clean	3.5	21
Sufficient air and space	2.3	14
Sufficient light	1.7	11
Enhance timber quality	1.3	8
Avoid competition by weeds	1.0	6
Pest prevention	0.7	4
Total	100	100

*Note: Because it was multiple choice questions, one person (STG) could give more than 1 answer. E.g.: Out of the 692 answers, 16% were "Better growth", and 97% of the farmers agreed that "better growth" is a benefit of weeding.

Table 8. Reasons to not weed perceived by tree growers. Percentage of smallholder tree growers who chose that specific answer and percentage of responses from the total amount of answers.

Reasons to not apply weeding	% of responses (n = 154)	% of STGs (n = 114)
Decrease seedling mortality	42.2	57
Weeding makes the soil dry	28.6	39
Specified that weeding makes soil dry depending on the month and weather	5.2	7
Specified that weeding makes soil dry depending on the site characteristics	3.2	4
Lack of capital	5.2	7
Lack of time	4.5	6
Death of seedlings due to circle weeding	2.6	4
No need cause of site characteristics	2.6	4
No circle weeding applied due to lack of knowledge	2.6	4
Other reasons	3.2	4
Total	100.0	100

Nearly all STGs acknowledged that weeding enhances and speeds up the growth of the seedlings, prevents fire hazard and improves woodlot accessibility. Farmers mainly agreed that weeding has a lot of benefits but depending on the site characteristics, the time of the year and the weather conditions when weeding is applied, it can cause the seedlings to die, mostly due to drought. It remained unclear if this would apply to both types of weeding or mostly to circle weeding.

About 86% of the STGs considered that they have good skills to apply proper weeding. Considering the different species, 29% of the farmers acknowledged that weeding of eucalyptus stands is more important than weeding of pine stands, while 58% thought that weeding of the two species is as important, and the rest 13% lacks the knowledge about this issue. Finally, concerning the perceptions of weeding, 96% of STGs agrees that in general weeding should always be applied.

Firebreaks rationale: 78% of the STGs found no reasons at all to not apply firebreaks. The main reasons to not prepare firebreaks were due to lack of time and money (Table 9). Only 3% of the STGs considered that fire was not a main concern for the future of their woodlots, so the vast majority of farmers acknowledged the relevant threat of fire in the region.

Table 9. Reasons to not prepare firebreaks perceived by the farmers. Percentage of smallholder tree growers who chose that specific answer and percentage of responses from the total amount of answers.

Reasons to not prepare firebreaks	% of responses (n = 122)	% of STGs (n = 114)
Lack of time	13	14
Lack of money	9	10
Other reasons*	3	4
Laziness	2	2
None	73	78
Total	100	100

* Other reasons to not apply firebreaks include: due woodlot distance from the household, due lack of weeds since herbicides were applied, because so far woodlots had never been affected by fire and because all the woodlots from the village are located in the same area therefore if fire arrives everyone is interested to extinguish it.

Pruning rationale: Practically all the tree growers believed that pruning increases the total revenues of their woodlots. Similar to the weeding rationale, pruning benefits in this table were also obtained by open-ended question and pre-established statement. The only benefit included on the statements was the quality enhancement; therefore, nearly all farmers agreed that it was a benefit (Table 10). The rest of the benefits were mentioned directly by the farmers. The majority of STGs (62%) reported that pruning allows trees to grow properly; many of them specified that the lack of pruning would increase the degree of taper in trees and growth would stagnate.

Table 10. Benefits of pruning perceived by the farmers. Percentage of smallholder tree growers who chose that specific answer and percentage of responses from the total amount of answers.

Benefits of pruning	% of responses (*n* = 266)	% of STGs (*n* = 114)
Enhance timber quality	42	98
For trees to grow properly	27	62
Nutrient optimization	11	26
For trees to grow straight	7	16
Sufficient space	6	13
Accelerate growth	4	10
Reduce fire hazard	2	4
To look clean	1	3
To obtain firewood	1	2
Total	100	100

Thinning rationale: Farmers' perceptions about thinning were mixed, 44% of the farmers agreed that thinning is good to increase the volume of the remaining trees on the stand, however 52% of farmers believed that there is no reason for thinning when the trees are spaced properly. Observing the results, we perceive that at least the majority of the farmers believed thinning is only applied in situations when: the initial spacing is not correct, there is double seedlings per pit, there is naturally regenerated trees, or the trees are not growing properly (probably due to lack of space).

Half of the farmers (51%) believed that thinning increases overall revenues thanks to the thinned and the remaining trees, 44% of STGs believed that thinning revenues come only from the remaining trees and the rest 5% believed that thinning does not increase revenues. This relates to the existence of markets for trees from thinnings (Table 11).

Table 11. STGs response rate concerning the existence of markets for thinned pines and eucalyptus.

Market for thinned pines and eucalyptus	% of STGs (n = 114)
Market for both	39
No market for any	28
Only market for thinned eucalypts	7
Only market for thinned pines	4
No market for pine, for eucalypt do not know	5
Market for pine, for eucalypt do not know	3
Lack of knowledge	13
Total	100

4.4. Factors influencing farmers' silvicultural activity

The attitudes and perceptions towards tree planting appeared to vary especially depending on the education level of the farmer. Farmers with perceptions such as *'it is important to wait until trees are big', 'distance to the woodlots is not a barrier', 'the pit size matters', 'there is a market for the thinned trees'* and *'silvicultural management activities are neither too expensive nor time consuming compared to the benefits'* were more educated than those farmers who thought the opposite of such perceptions (Table 12). Likewise attitudes and perceptions varied depending on the farmer's age. Younger farmers had more similar perceptions to farmers with higher education (Table 12).

Positive attitudes towards silvicultural activities – at least for weeding and firebreaks – (measured by the complete acknowledgement of all the benefits included in the pre-established statements in the questionnaire) had a positive influence on the level of management applied on the woodlots (Table 12). Likewise, sceptic attitudes resulted in lower application of activities. Furthermore, at least for weeding, the perceived skills of the farmer – i.e. the farmer believes to have good skills to apply weeding – appeared to influence positively the level of management applied. Because the attitudes and perceived skills of the other management activities were similar amongst the farmers, their influence could not be assessed.

Certain knowledge or perceptions on silvicultural management (i.e. farmer's understanding of: stand density, final tree size, pit size, differences between weeding of pines or eucalypts, market for thinned trees, and benefits of weeding, pruning and thinning compared to the time and capital spend on these activities) between the farmers interviewed did not appear to have an effect on the level of management applied (Table 12).

Nearly all farmers considered fire as a major hazard; therefore, this could not serve as explanation for the level of firebreaks applied. Surprisingly, there was no difference on the firebreaks application between farmers whose woodlots had, and had not, been affected by fire.

Tree growers, who grew agricultural crops between the rows of trees, had applied significantly more slash weeding ($p = 0.029$).

Land tenure security, contentment and motivation towards tree planting, species selection and seedling origin were very similar amongst all farmers. Thus, all these characteristics could not serve as explanatory variables for the differences found on the level of silvicultural management.

Farmers who belonged to a tree-growers' association and/or farmers who received external support applied significantly more activities for the management of their woodlots (silvicultural management all together, circle weeding and firebreaks) than farmers who were not engaged on TGA nor received support from a major forestry program (Table 13). The gender of the farmers did not seem to have an effect on the level of silvicultural management (Table 13).

The socio-economic factors found to be significant and positively correlated to level of silvicultural management were (Table 14):

- Age of the farmer (*silvicultural management all together*)
- Number of household members (*silvicultural management, circle weeding and firebreaks*)

- Number of children at school (*silvicultural management, circle weeding and firebreaks*)
- Total household land area (*silvicultural management and negatively correlated for firebreaks*)
- Number of years planting trees (*slash weeding and negatively correlated for firebreaks*)
- Years of membership to a tree-growers' association (*circle weeding*)
- Number of direct incentives (*silvicultural management and circle weeding*)
- Number of permanent workers (*silvicultural management and circle weeding*).

The socio-economic characteristics not correlated to the level of silvicultural management were (Table 14):

- Education level
- Annual household income classification
- Percentage of the tree-planting area from the total household land area
- Average distance from household to the woodlots
- Number of temporary workers

Table 12. Comparison of farmer's attitudes and perceptions depending on farmer's education level and age; and difference on the level of silvicultural management between farmers holding, or not, such perceptions.

				Differences amongst age and education				Influence to silvicultural management							
				Age (years old)		Education level (0 - 3)		Level of silvicultural activities* (0 - 10)		Level of circle weeding* (0 - 4)		Level of slash weeding* (0 - 4)		Level of firebreaks* (0 - 3)	
Farmers' attitudes and perceptions		*n*	% of STG	mean ± std	*p*	mean ± std	*p*	mean ± std	*p*	mean ± std	*p*	mean ± std	*p*	mean ± std	*p*
Considers that it is beneficial to have a certain stand density	No	59	52	43.59 ± 12.28	NS	1.22 ± 0.65	NS	6.47 ± 2.20	NS	1.95 ± 1.76	NS	2.31 ± 1.63	NS	1.80 ± 1.05	NS
	Yes	55	48	44.04 ± 12.13		1.36 ± 0.65		6.64 ± 1.67		1.48 ± 1.40		2.30 ± 1.33		1.84 ± 0.92	
Considers important to wait until trees are big	No	48	42	46.21 ± 12.02	NS	1.02 ± 0.33	***	6.60 ± 1.94	NS	1.85 ± 1.69	NS	2.40 ± 1.59	NS	1.83 ± 1.00	NS
	Yes	66	58	42.06 ± 12.05		1.48 ± 0.75		6.52 ± 1.98		1.62 ± 1.54		2.23 ± 1.41		1.80 ± 0.98	
Considers distance is not a barrier to the silvicultural management	No	87	76	46.18 ± 11.25	***	1.17 ± 0.58	***	6.43 ± 2.12	NS	1.66 ± 1.62	NS	2.11 ± 1.54	*	1.75 ± 1.04	NS
	Yes	27	24	36.15 ± 11.99		1.67 ± 0.73		6.96 ± 1.26		1.92 ± 1.55		2.92 ± 1.13		2.04 ± 0.76	
Believes pit size makes a difference to the future performance of the tree seedlings	No	76	67	46.63 ± 11.52	***	1.14 ± 0.56	***	6.54 ± 1.91	NS	1.75 ± 1.64	NS	2.30 ± 1.49	NS	1.88 ± 0.92	NS
	Yes	38	33	38.16 ± 11.56		1.58 ± 0.72		6.58 ± 2.06		1.65 ± 1.55		2.30 ± 1.51		1.68 ± 1.09	
Very positive attitude towards weeding*	No	25	22	42.96 ± 12.81	NS	1.36 ± 0.76	NS	5.56 ± 1.71	**	0.83 ± 1.37	***	1.64 ± 1.63	*	2.00 ± 0.82	NS
	Yes	89	78	44.04 ± 12.03		1.27 ± 0.62		6.83 ± 1.94		1.97 ± 1.58		2.49 ± 1.40		1.76 ± 1.02	
Sceptic towards weeding depending on conditions*	No	36	32	40.92 ± 11.40	NS	1.50 ± 0.70	**	7.39 ± 1.52	**	2.37 ± 1.37	***	2.67 ± 1.20	NS	2.17 ± 0.88	**
	Yes	78	68	45.14 ± 12.34		1.19 ± 0.60		6.17 ± 2.02		1.41 ± 1.62		2.13 ± 1.58		1.65 ± 0.99	
Considers to have good skills to apply weeding	No	16	14	39.81 ± 9.88	NS	1.25 ± 0.58	NS	4.50 ± 1.46	***	0.29 ± 0.61	***	1.13 ± 1.13	***	1.44 ± 1.15	NS
	Yes	98	86	44.46 ± 12.41		1.30 ± 0.66		6.89 ± 1.82		1.93 ± 1.60		2.48 ± 1.46		1.88 ± 0.94	
Acknowledges that weeding of eucalyptus is more important than weeding of pine	No	81	71	42.22 ± 12.12	*	1.37 ± 0.66	*	6.64 ± 1.99	NS	1.86 ± 1.60	NS	2.29 ± 1.45	NS	1.88 ± 1.02	NS
	Yes	33	29	47.70 ± 11.50		1.09 ± 0.58		6.33 ± 1.88		1.38 ± 1.58		2.33 ± 1.59		1.67 ± 0.89	
Very positive attitude towards firebreaks*	No	25	22	39.24 ± 12.31	*	1.20 ± 0.41	NS	5.28 ± 1.79	***	1.24 ± 1.59	NS	1.88 ± 1.54	NS	0.76 ± 1.01	***
	Yes	89	78	45.09 ± 11.87		1.31 ± 0.70		6.91 ± 1.86		1.86 ± 1.59		2.42 ± 1.46		2.11 ± 0.75	
Believes there is market for the thinned trees[2]	No	53	46	46.06 ± 12.48	NS	1.02 ± 0.37	***	6.30 ± 1.98	NS	1.48 ± 1.59	NS	2.25 ± 1.52	NS	1.74 ± 1.06	NS
	Yes	61	54	41.85 ± 11.62		1.52 ± 0.74		6.77 ± 1.93		1.93 ± 1.60		2.34 ± 1.47		1.89 ± 0.92	
Considers weeding is neither too time consuming nor expensive compared to the benefits	No	71	62	46.20 ± 11.68	**	1.06 ± 0.41	***	6.48 ± 1.88	NS	1.65 ± 1.57	NS	2.24 ± 1.52	NS	1.83 ± 0.94	NS
	Yes	43	38	39.86 ± 12.04		1.67 ± 0.78		6.67 ± 2.09		1.83 ± 1.67		2.40 ± 1.45		1.79 ± 1.06	
Considers pruning is neither too time consuming nor expensive compared to the benefits	No	53	46	48.87 ± 10.68	***	0.98 ± 0.31	***	6.53 ± 1.99	NS	1.72 ± 1.58	NS	2.23 ± 1.52	NS	1.72 ± 1.05	NS
	Yes	61	54	39.41 ± 11.72		1.56 ± 0.74		6.57 ± 1.95		1.72 ± 1.64		2.37 ± 1.47		1.90 ± 0.93	
Considers thinning is neither too time consuming nor expensive compared to the benefits	No	54	47	48.67 ± 10.66	***	1.04 ± 0.47	***	6.46 ± 2.07	NS	1.59 ± 1.54	NS	2.33 ± 1.48	NS	1.69 ± 1.04	NS
	Yes	60	53	39.43 ±11.83		1.52 ± 0.70		6.63 ± 1.86		1.83 ± 1.66		2.27 ± 1.51		1.93 ± 0.92	

Notes: NS (not significant) = ≥0.05, * = ≤0.05, ** = ≤0.01, *** = ≤0.001. Mann-Whitney U test was used to assess if there was a significant difference in the perceptions of the farmers depending on their age and education and to determine if such perceptions influence the level of silvicultural activities. *All the indicators and variables are explained in the methodology section. [2]For either thinned pines or eucalypts or both.

Table 13. Comparison of the level of silvicultural management between: (a) Farmer with and without the external support; (b) farmers belonging to a tree-growers' association and farmers who do not; and (c) female and male.

	With support (n = 92)	Without support (n = 22)		TGA-member (n = 97)	Non-TGA member (n = 13)		Female (n = 41)	Male (n = 73)	
	mean ± std	mean ± std	*p*	mean ± std	mean ± std	*p*	mean ± std	mean ± std	*p*
Level of silvicultural management (0 - 10)	6.80 ± 1.84	5.50 ± 2.13	**	6.72 ± 1.83	5.50 ± 2.39	*	6.32 ± 1.96	6.68 ± 1.96	NS
Level of circle weeding applied (0 - 4)	1.93 ± 1.61	0.68 ± 1.11	**	1.85 ± 1.62	0.77 ± 1.17	*	1.51 ± 1.62	1.83 ± 1.60	NS
Level of slash weeding applied (0 - 4)	2.26 ± 1.53	2.48 ± 1.29	NS	2.32 ± 1.52	2.20 ± 1.32	NS	2.32 ± 1.53	2.29 ± 1.48	NS
Level of firebreaks applied (0 - 3)	1.92 ± 0.92	1.36 ± 1.14	*	1.87 ± 0.95	1.50 ± 1.16	NS	2.02 ± 0.94	1.70 ± 1.00	NS

Notes: NS (not significant) = ≥0.05, * = ≤0.05, ** = ≤0.01. Mann-Whitney U test was used to compare the groups.

Table 14. Farmers' socio-economic characteristics and Spearman correlations for level of silvicultural management and socio-economic variables.

Socio-economic variable				Level of silvicultural management	Level of circle weeding	Level of slash weeding	Level of firebreaks
	n	Mean	SD	r	r	r	r
Age of the farmer (years)	114	43.81	12.16	0.19*	0.01	0.11	0.11
Education level (0-3)	114	1.29	1	0.16	0.14	0.08	0.13
Number of household members	114	5.14	2.23	0.27**	0.29**	0.07	0.27**
Number of children at school	114	1.82	1.42	0.28**	0.22*	0.06	0.34**
Annual household income classes (1-8)	112	4.46 (~ TZS 1 million)	1.69	0.01	-0.01	-0.09	0.1
Tree-planting area of the total household land area (%)	114	51.36	19.59	0.14	0.05	-0.01	0.03
Total household land area (hectares)	114	12.94	28.13	0.20*	0.09	0.16	-0.19*
Number of years planting trees	114	14.31	10.48	0.13	0.08	0.23*	-0.19*
Years of membership to a tree growers association	98	1.79	1.28	0.16	0.21*	0.09	-0.16
Number of direct incentives	114	1.34	1.05	0.28**	0.29**	0.07	0.04
Average distance from household to the woodlots (km)	114	4.5	4.22	-0.1	-0.12	-0.11	0.03
Number of permanent workers (paid and HH members)	114	2.01	1.05	0.19*	0.21*	-0.02	0.09
Number of temporary workers (paid and HH members)	114	4.43	7.77	0.05	-0.06	0.07	-0.14

Note: * = p < 0.5, ** = p < 0.01

Since all farmers applied pruning, no further analysis could be done regarding this management activity.

Lastly, farmers who applied thinning or had the intention to do it were significantly older, had been practicing tree planting for longer time and had more land (Table 15). The rest of the socio-economic characteristics, participation on TGA, given supports, attitudes or perceptions of the farmers did not differ between (a) farmers who applied thinning or had intention to do it; and (b) farmers who had not applied thinning nor had the intention to do it.

Table 15. Comparison of socio-economic characteristics between: (a) farmers who applied thinning or had intention to do it and (b) farmers who had not applied thinning nor had the intention to do it.

	Thinning applied (n = 71) mean ± std	Thinning not applied (n = 43) mean ± std	p
Age of the farmer	45.73 ± 12.17	40.63 ± 11.59	*
Number of years planting trees	16.73 ± 10.95	10.30 ± 8.32	*
Total HH land area (hectares)	15.61 ± 34.80	8.52 ± 8.88	**

Note: * = ≤0.05, ** = ≤0.01. Mann-Whitney U test was used to compare the groups.

4.5. Farmers' opinions on how to enhance woodlot management

Most of the farmers (45%) believed that loans would be the best type of support to enhance the management of their woodlots (mainly to hire contractors to manage the tree plantations or the agricultural crops, so farmer itself would have more time to put in the silvicultural management). The second most preferred support was training, followed by cash. Other supports seldom mentioned included infrastructure (such as roads) and tools (incl. fertilizers, tools for pruning, improved seedlings and herbicides).

4.6. Summary of main findings

(1) What silvicultural activities do smallholder tree growers apply for the management of their woodlots? How and when are these implemented?

Hypothesis: Farmers in general do not prioritize the management of tree plantations. Silvicultural activities are randomly and seldom applied.

Findings: From the initial hypothesis, it is true that farmers prioritized agricultural activities over tree management. Silvicultural management varied between woodlots of the same household and between seasons. Rather than applying or not a certain management activity, the key relied on how and when these management activities were applied. A quarter of the farmers applied only pitting during site establishment, while the rest cleared-slashed the plot in addition. Clearing by fire, circle weeding and removal of native trees was also done by some of the farmers during site establishment. Slash weeding of young plots was more widely applied than circle weeding. However, even when weeding was applied, only a quarter of the farmers did it every season to all the young woodlots. Moreover, weeding was rarely applied twice in a season and the timing would depend on the calendar of other labour-intensive income activities rather than prioritizing the right timing for weeding. While 73% of farmers prepared firebreaks, only 25% prepared them for all the woodlots of the household. Pruning was applied or planned to be applied by all tree growers in 4-year-old woodlots for the first time and 2.5 times per rotation on average. Two thirds of the farmers applied or were planning to apply thinning in 4.2-year-old woodlots for the first time and 1.6 times per rotation on average. Pine rotation age was 13 years on average and eucalyptus rotation age was 12 years on average. Silvicultural activities were widely applied by the household members, except for building firebreaks which was commonly done by TGA cooperation. Instruction by experts played a significant role on farmers' decision to apply silvicultural management

(2) What perceptions and rationale do STG have for silvicultural management?

Hypothesis: Farmers have the generalized perception that silvicultural management is not crucial for the performance of tree plantations; trees require little input after they are planted, if any. So, farmers do not perceive the benefits of managing the woodlots.

Findings: In contrast to our hypothesis based on the broadly spread perception that tree growers in Africa do not perceive the benefits of managing their woodlots; results demonstrate that a vast majority did recognize the benefits; and furthermore, a considerable proportion believed that these silvicultural management activities were neither too time consuming nor expensive compared to the benefits. The benefits of pre-established stand densities and full-size tree diameter were recognized by roughly half the farmers. Price premium for straight and knotless logs was recognized by nearly all farmers. Despite the wide variations on silvicultural management activities, practically all tree growers considered that their woodlots are in good condition and grow well. Practically all farmers considered the lack of time and capital, the main barriers to enhance woodlot management. All the tree growers from this study recognized the benefits of weeding of young woodlots and agreed that in general it should always be applied. There were however considerable concerns towards weeding causing death of the seedlings in certain circumstances. Fire was a main concern for all. The enhancement of timber quality by pruning the stands was acknowledged by all farmers. Thinning was generally understood as an activity that should only be carried out in cases where: the initial spacing was not correct, there was double seedlings per pit, there was naturally regenerated trees or the trees were not growing properly.

(3) What factors influence the adoption or the level of application of the silvicultural management?

Hypothesis: Farmers silvicultural management activities are influenced by the socio-economic characteristics of the farmer and the household; characteristics of the farm; extension and external support received; farmer's participation in tree growers associations; farmer's attitudes and perceptions towards silvicultural activities; skills and knowledge; and, access to attractive markets.

Findings: Our hypothesis was proven mostly true. A positive or sceptic attitude towards certain silvicultural activities and the farmer's perceived skills influenced the level of management applied. However, based on the results, certain knowledge or perceptions on silviculture did not affect the level of silvicultural management. Furthermore, the socio-economic characteristics of the farmer and the household and the characteristics of the farm influenced the level of silvicultural management applied by the farmers. External support from a major forestry program and farmer's participation in a tree-growers' association had an important role especially on site preparation and the application of circle weeding and firebreaks.

(4) What improvements could be done by organizations providing external support so that farmers would further engage in the management activities of their woodlots?

Hypothesis: Farmer's access to capital and further extension on tree planting engages farmers to the management activities of their woodlots. However, favourable policies, the development of forest industry – including networks which allow the cooperation and communication between all stakeholders – and farmers' access to markets will play the most significant role ultimately.

Findings: To fully assess our hypothesis, only the results of this study were not enough. To provide more useful and comprehensive recommendations, this last research question will be analyzed on the discussion section using results from other studies in the same area. In any case, access to loans and training were the most preferred support by tree growers to enhance silvicultural management. Based on the results, training should be more case dependent and emphasis should be put on the timing of these activities. Finally, unless farmers have the sufficient resources to contract labour force, tree planting activity needs to fit on the farmer's calendar of other income generating activities.

5. DISCUSSION

5.1. Current silvicultural practices applied by tree growers

Farmers, in most of the cases, were conducting the management of the woodlots by themselves and mostly due to instruction by forestry experts. However, the application of silvicultural activities does not mean necessarily that they are performed adequately to enhance the performance of the woodlots. For example, most of the farmers were instructed to apply weeding and they believed to have good skills to weed. However, more than half of the farmers indicated that weeding may increase seedling mortality depending on the site and weather conditions (e.g. given too dry soils or too dry weather, too intense weeding could dry the tree seedlings). Furthermore, nearly all tree growers believed that weeding is beneficial and in general it should always be applied. Nevertheless, only a quarter of the tree growers weeded all the required young woodlots every season.

We can perceive a lack of precise and accurate knowledge on how to apply weeding, including all relevant factors without which, weeding may even be prejudicial for the tree seedlings. Relevant factors include: site characteristics, timing of the activity depending on the site, the climate and the current weather conditions, the intensity of weeding and how frequently the weeding should be applied.

Results indicate that this generalization of the management activities was to some extent coming from the forestry experts and then transmitted to the tree growers. Previous studies repeatedly mention lack of technical knowledge and training as a limiting factor to improve silvicultural activity among smallholder tree growers (Byron 2001). Furthermore, they emphasized the importance of forestry extension programs working closely with local farmers and providing technical information (Salam et al. 2000). Kallio (2013) demonstrated how just conducting silvicultural practices did not in itself cause the variation in farmers' plantation performance and she argued that the quality of the stands was likely to depend on the site as well as the specific methods and timing used for the silvicultural management. This study revalidates such results and in addition, it points out that even though progress was made, and extension providers were

working closely with the farmers, there is still much space for improvement on the accuracy and consistency of the technical information provided to farmers.

Other management activities suggest similar outcomes. Even though the amount of treatments during site preparation and establishment increased after the extension, other harmful practices such as removal of native trees remained on the same level whereas practices like clearing by fire even increased. Moreover, clearing of native woodlands was often reported. In this case, extension was not adequate and it might have even promoted practices that can cause negative environmental impacts.

PFP guidelines however, do not promote such practices; it is strictly forbidden to clear native woodlands; and there is no mention of clearing by fire, neither promoting it nor forbidding it (PFP 2017a). Therefore, the information was lost at some point of the chain from forestry experts, passing through extension officers to the farmers. Monitoring and evaluation to identify such short-comings and to provide evidence that communication needs to be more effective, is key. A previous study on the specific topic of communication emphasized that evaluating the strengths and limitations of existing extension systems is essential to inform future farm forestry development strategies (Glendinning et al. 2001). The study by Glendinning reported that communication skills of the extension agent require an effective flow of information, because mere extension-farmer contact does not necessarily initiate the process of change.

In the case of firebreaks, the average reported width (6.7 meters) was well below the recommended width from the extension – at least 20 meters (PFP 2017a). In relation to thinning, even though a considerable number of farmers affirmed that they received instructions, their understanding of thinning was limited and more than a third of tree growers never applied thinning nor was planning to do it. Both examples reaffirm the urgency for effective extension and training which needs to be customized for the target group (Glendinning et al. 2001).

Lastly, farmers tended to prioritize the management of some of their woodlots; especially the ones which were planted with incentives (seedlings) from the forestry program, and leaving the other woodlots unmanaged. Thus, reflecting the lack of

commitment and engagement with tree planting unless there are incentives available. Essentially this means that for at least a big proportion of the farmers, tree planting was not yet an attractive enough livelihood option to which efforts and resources had to be fully invested but rather an activity which might bring benefits because incentives were provided. Endorsing the study by Arvola et al. (2019); farmers, which usually had limited resources, prioritized the agricultural activities over plantation management.

5.2. Farmer's perceptions and rationale behind silvicultural activities

There was a dual perception towards tree size and stand density. About half of the farmers recognized the benefits of having full-sized trees and therefore, accepted the longer rotation ages; while the other half considered more beneficial to maximize the amount of trees independently of their size. Both perceptions have their legitimacy based on the context, which depends on the markets. Market incentives are discussed later on the report.

Farmers acknowledged many of the benefits that silvicultural management such as weeding, pruning and thinning provide. Many of the interviewed tree growers changed their perceptions towards woodlot management after seeing the positive effects of management on demonstration plots and testing it on their own woodlots. Moreover, peer example was the main driving reason to start tree planting. Previous studies emphasized the relevance of imitated planting from neighbours and relatives as well as the mechanism of learning by doing (Walters et al. 2005; Kallio 2013).

Farmer's perceptions towards silvicultural activities are further discussed on the next section, where the influence of such perceptions on the level of silvicultural management is also assessed.

5.3. Factors influencing farmers' silvicultural activity

5.3.1. Attitudes and perceptions

The results of this study endorse similar findings in other study cases from tropical countries (Mahapatra and Mitchell 2001; Kallio et al. 2011); a positive attitude towards silviculture leads to higher levels of management. In addition, sceptic attitudes towards certain management activities may reflect in lower engagement. Sceptic attitudes in this study were caused by the lack of knowledge on the right timing or the right conditions when to apply certain activities, such as weeding. Moreover, farmer's perceived skills had a positive effect on the level of management, thus emphasizing the importance of training and adequate extension on tree planting and woodlot management.

Farmer's knowledge and perceptions towards silvicultural management varied amongst education level and age of the farmer. Based on the results, certain perceptions did not influence the level of management applied. Farmers applied management activities independently of their belief if such activities were too time consuming or too expensive compared to the benefits. One explanation may be that farmers did not fully understand the meaning of the statement; since one would imagine that *if a farmer considered that the management activities were not profitable, he would not apply them*, and thus we would have found a correlation. Moreover, higher educated farmers more often considered that such activities were neither too time consuming nor expensive compared to the benefits.

Previous studies concluded that farmers do not fully recognize the importance of proper silvicultural management to enhance their plantation productivity and quality (Kallio 2013). In this study, farmer's perceptions varied among specific silvicultural management activities, however the results prove that farmers did perceive the benefits of managing their woodlots. Moreover, nearly all farmers believed that their trees could grow better if they could allocate more time and money to silvicultural management.

Even though, proper and complete silvicultural management to all household woodlots was low, only few farmers (6%) considered that their woodlots were of low

performance. Based on the results of an extensive field survey in the same area of this study (including ten out of the twelve villages from this study), the performance of tree plantations (i.e. survival rate and height growth) could be enhanced if better silvicultural management was applied (PFP 2017b). Therefore, results from this study endorse the fact that (1) farmers may not fully understand the need to further engage on the management of their woodlots because they believe that their plantations perform well enough under the current management and (2) in many cases, farmers do not have a need for investing more resources because it is good enough for them as it is, because at the end, tree planting is a secondary activity (Kallio 2013). The perception of "good-enough performance" is related to the other livelihood strategies that farmers have but also to the markets, which is discussed later on.

Almost all tree growers considered that lack of time and capital were the main barriers to further engage on the management of their woodlots. Such results are consistent with much of the literature previously reviewed (Byron 2001; Walters et al. 2005; Kallio 2013). Lack of resources measured either in time, because household labour force is dedicated to other activities; or in capital, because there is not enough capital to hire labour force; is a major constraint to woodlot management.

Weeding of young woodlots is critical for the survival and fast growth of the tree seedlings (Imo 2009). This was also emphasized by the results from the extensive field survey in the same study area (PFP 2017b). Intercropping of maize on the woodlots has been often discussed as a practice which may have negative effect on the growth of the tree seedlings (Muchiri et al. 2002). Other studies however support the improved tree seedling survival and growth on taungya systems with *Pinus patula* and maize, thanks to the reduced weed competition (Imo 2009). This study supports the fact that those who applied agroforestry, with either maize or legumes, applied more slash weeding than those who did not.

Secure access and rights to land is one of the keys for sustainable tree growing (Byron 2001; Snelder and Lasco 2008). A closely related study on the same area (Arvola et al.

2019) revalidates the results of this study; farmers considered the ownership of their woodlots as sufficiently secure.

5.3.2. External support, extension and participation in farmers' group

Lack of technical knowledge is frequently mentioned as a factor limiting farmers' silvicultural activity in developing countries (e.g. Byron 2001). Tanzania is not an exception; as identified by the National Forest Policy (The Forest Act 2002) and later emphasized by regional actions plans (Simula et al. 2009), the technical guidelines and extension services are inadequate; and tree growers are currently lacking sufficient skills and knowledge. Nevertheless, sound extension services are likely to have a positive effect on tree planting activity and management (Salam et al. 2000).

Based on the experience, governments have been taking the lead role to promote reforestation. In most of the cases, the same silvicultural advice is given to all landholders, independently of their characteristics and interests; thus leading to failure (Lamb 2011). The extension and information given to farmers has to be relevant to their needs. The most trust-worthy sources of information will be those coming from within the community (Lamb 2011). Farmers from this study showed higher satisfaction with the extension provided by long-term village-based extension officers, than the extension coming from government officials sporadically. To add to previous studies, it is important that extension is coherent and detailed. Extension should be specific for the target group, but also for the site characteristics and the climatic conditions of the tree plantations.

This research provides evidence that farmers receiving incentives from a tree-planting program applied significantly more silvicultural activities. However, when looking closely, for certain management activities such as slash weeding or thinning, no significant differences were found between farmers with or without external support. Moreover, there is sufficient evidence that farmers tended to prioritize some woodlots over others. As Lamb (2011) criticizes, based on a review of case studies from the Asia-Pacific, direct incentives such as free seedlings, cash or loans, tend to perpetuate a

dependency on external support, and usually the improvements achieved through these direct incentives will cease once the support is withdrawn. In this case study, some farmers engaged on the management of woodlots which were established with the direct incentives while leaving aside the management of other woodlots.

Success is often achieved when dependence on government support is reduced over time (Lamb 2011). The ultimate goal of incentives should be: to achieve a resilient socio-economic system without need for continued external support. One way of achieving this is by developing networks and institutions able to learn, store and exchange knowledge (Lamb 2011).

Learning networks are cooperative partnerships between landholders, enterprises, government and other interested people in tree plantations (Lamb 2011). Such networks should have a fair representation – and allow the participation – of all the stakeholders. Such networks can help ensure that the multiplicity of goals is acknowledged by all stakeholders. Networks such as tree-growers' associations, can ensure the sustainability of support to tree growers beyond donor-funded incentives schemes.

The results of this study are consistent with previous ones (Bebbington 1996; Kallio 2013); participation in social organizations is beneficial for learning new or improved practices. That was the case for site preparation and establishment, circle weeding and firebreaks; all of which were introduced or improved during the extension provided by the forestry program. After the training of extension officers, technical advice was given to farmers via the tree-growers' association. Furthermore, it is through these tree-growers' associations that farmers themselves can identify and set the priorities for the information to be propagated (Glendinning et al. 2001).

5.3.3. Other socio-economic factors

Earlier studies from the tropics found that farmers silvicultural management activities are influenced by the socio-economic characteristics of the farmer and the household

(Pattanayak et al. 2003) and characteristics of the farm (e.g. Summers et al. 2004; Kallio 2013).

Age and years of experience: The age of the farmer and the amount of years planting trees, represents at least to some extent the experience of the farmer; therefore, it influences the adoption of new technologies, as found in previous research (Pattanayak et al. 2003); and the level of silvicultural management, as found in this study.

Gender: The gender of the respondent was not significant based on the results from this study. Previous studies found that household with higher proportion of males were more likely to adopt new forestry technologies (Pattanayak et al. 2003). Though such variable was not collected during the interviews.

Education level: Previous studies suggested that education might be a proxy for opportunity costs of labour investment (Pattanayak et al. 2003). In this study, the lack of time and capital were the main reasons to not further engage on the management of tree plantations, mainly because time and capital (household or paid labour force) were being invested on other income generating activities, mainly agriculture. However, no correlation between level of education and the level of silvicultural management was found; probably because the sample was highly skewed towards primary education, with very few respondents with none or high education.

Income, assets and labour force: Households with larger incomes and more labour or land available are more likely to invest in new activities because they have the required risk capital (Hyde and Amacher 2000; Mercer 2004).

According to the results of this study and previous studies (Pattanayak et al. 2003; Kallio 2013), the number of household members, which serves as a proxy for labour force, was positively correlated to the level of silvicultural management. Likewise, the number of permanent workers influenced the level of silvicultural activities.

Number of children at school may serve as an indicator for wealth or assets available. The classification of total household income used for this study may not be very reliable because it was very roughly measured by directly asking to the interviewees. That is

probably the reason why there was no correlation between the income classification and the level of silvicultural management; but instead, a positive correlation between the number of children at school and the level of silvicultural management was found.

Household land area: Total household land area was described before to influence the tree planting activity (Pattanayak et al. 2003; Summers et al. 2004). Land holdings in this study were positively correlated to the level of management. Although, specifically for the level of firebreaks applied, the correlation was negative. Hence it suggests that households owning greater areas of land may lack the capacity to properly protect their woodlots. It was rather surprising to find that farmers with more experience tended to build fewer firebreaks. However, the reason for this may be the same as before, because farmers with more experience in tree planting also owned larger areas of tree plantations.

The percentage of tree-planting area was not correlated to the level of silvicultural management; which may further support the above mentioned interpretation. Larger areas of tree plantations are more difficult to fully manage and protect. Although at the same time, larger areas of tree plantations, means more available resources to engage in silvicultural management. This dual negative and positive influence may be the reason why no correlation was found. Previous studies found a similar inconsistency of positive and negative correlation between plot size and adoption of new technologies (Pattanayak et al. 2003).

Years of membership to a TGA: Circle weeding was unknown by farmers who did not receive any training; and according to farmers, it was a recently introduced management activity. Therefore, it is reasonable that farmers with longer membership to a TGA, who presumably have more trust on the association, would be more receptive to the introduction of new technologies (such as circle weeding); as it was found in this study.

Number of direct incentives: The number of direct incentives received for tree planting was positively correlated with the level of management, mostly because of weeding, since one of the direct incentives was the cash-incentive for weeding.

Distance from the household to the woodlots: The average distance from the farmer's household to their woodlots did not influence the level of silvicultural management. Partly, the lack of correlation can be explained by the difficulties to measure such variable – i.e. different paths to the woodlots and different measurement units (time, kilometres).

5.3.4. Market incentives

Less than half of the farmers (40%) already sold trees; mostly to middlemen. About a quarter of the farmers, who did not yet sell any trees, lacked the knowledge about the market options available. The age of final harvesting had large variations among farmers; but in any case, rotation periods are too short from the wood quality point of view (Arvola et al. 2019). Results indicate that farmers had limited information about the different market options available. This supports previous studies which also identified the need for market information systems which allow stakeholders along the value chain to know its potential customers and/or suppliers (Scherr 2004; PFP 2016a).

As Byron (2001) highlighted, one of the key factors to success in sustainable tree planting is the availability of an attractive market that farmers can have access to. In order to improve the access to markets, farmers need to know the wood price for different qualities and need to be able to measure the real value of their plantations (Perdana et al. 2012). Market information is useful to smallholder tree growers, to be aware of the potential benefits of producing full-sized quality trees; and for the larger investors, to develop new projects based on the potential raw material supply lines.

In a market situation where wood demand largely exceeds the supply, markets buy any available raw material, independently of its quantity, quality and price (Kallio 2013). Even though at the moment there was little incentive to maximize productivity and quality; as Arvola (2019) stressed, by the time that timber quality is internalized on the pricing, farmer's lack of engagement in forest management will restrict their access to the markets. Moreover, the incentive for management also comes through better growth rates and so shorter rotations (Arvola et al. 2019).

The study by Arvola (2019) found that even though wood demand is high and likely to remain high in the future, farmers' access to wood markets is limited and their negotiation power is weak. Nowadays the markets accept the quality of wood produced by smallholders (Arvola et al. 2019). However, following the market demand, whenever a product of higher quality is available in the future for the same price – such as imported wood – locally grown timber might be replaced.

On the value chain analysis made by Private Forestry Programme (PFP 2016a) they identified little price differences between large and small diameter saw log stumpage prices; which seems contradictory since smaller diameter logs have lower sawmill recovery rates and thus should cost less. Furthermore, the same study found that price premium for better quality sawn timber is currently inexistent at the study area. Nevertheless, local markets cannot absorb all the volume produced and most of the timber is transported and sold in Dar es Salaam or other major cities. The biggest market of the country is in Dar es Salaam and there, better quality sawn timber has a noticeable price premium – one quarter higher prices than poor quality timber.

Producing full-sized and high quality sawn timber with improved sawmill recovery rates would increase profit margins throughout the value chain (PFP 2016a). The potential earnings from sawn timber processing are not yet realized due to the inefficiency in logistics together with the sawmills inability to account for the benefits of economies of scale because of the small sizes and the lack of raw material (PFP 2016a). All of which emphasizes the importance of producing full-sized and quality logs in order to maximize the benefits of commercial tree planting, and its potential contribution to rural development.

The lack of information about markets and the increasing roundwood supply deficit (i.e. farmers could easily sell any type wood, despite its size and quality) was likely to influence farmers on their perception that their woodlots were performing well enough. In this study, all farmers had the same market incentives and nearly all farmers considered their woodlots to perform well, thus it was not possible to measure if market incentives influenced the level of silvicultural management.

5.3.5. Access to finance

As demonstrated by the results of this study, farmer's lack of resources was the main barrier to further engagement on silvicultural activities. Moreover, farmers believed that access to loans, apart from training, would be the best type of support to improve woodlot management. Loans from traditional banks are not accessible for the poorest farmers, who do not have the required collaterals. An alternative source for loans could be the Village Savings and Loans Associations. VSLA is a group of people who pool their savings to have a source of lending funds; members make savings contributions to the pool and can also borrow from it. Evidence from the rural poor in Ghana, Malawi and Uganda, showed a positive impact of VSLAs on household business outcomes and improved resilience to climatic calamities (Karlan et al. 2011). Furthermore, the increased savings and credit obtained through VSLAs led to an increase in agricultural investments and income from small businesses in Northern Malawi (Ksoll et al. 2016). Therefore, it is likely that such system, if carefully implemented, could result in positive outcomes in the context of tree planting as well. During the realization of this study, VSLAs were recently introduced in the Southern Highlands of Tanzania and it is still too early for assessing the outcomes.

Finally, it is worth to mention 'out-grower schemes' as a potential arrangement that could improve farmers' access to markets, and provide credit facilities at the same time. In South Africa but also in other countries, there are successful out-grower schemes which benefit both large private firms and thousands of smallholder tree growers. Under the most successful out-grower schemes, firms usually provide to farmers free expertise, silvicultural training and high-quality seedlings, advance payment for work and a guaranteed market for their trees at current market prices (Mayers 2000). In some cases, such schemes also benefited communities through the provision of infrastructure (e.g. roads) and increased employment opportunities.

5.4. Limitations of the study

This study was conducted in the context of a major forestry development program, which was operating in the study area and provided the resources to carry out this research. Some compromises had to be made and not all the villages or respondents selection was optimal. This context led to a large sample of farmers under the support of the program and relatively small sample of farmers without such support. Moreover, the large extent of the mentioned program was likely to influence farmers even on the villages which were not yet receiving any direct incentives. Even though the independence of the current research and its detachment from the forestry program was explained and emphasized to the farmers, the fact that the researcher was coming together with the program's staff would likely give farmers the perception that the study was part of the program. Therefore, their answers could be partially influenced by such fact, and some farmers may have shown too positive attitudes towards tree planting in the fear of losing the tree planting incentives. However, each farmer was personally informed at the beginning of each interview that their answers would have no influence on the incentives that they were currently receiving.

6. CONCLUSIONS AND RECOMMENDATIONS

The current study aimed to characterize and explore the factors which influence the silvicultural management activities applied by smallholders on commercial tree plantations in the Southern Highlands of Tanzania. The results of this study provide useful information for the implementation of tree-planting programs aiming to develop small-scale sustainable tree plantations. The ultimate goal is a better success of small-scale commercial tree growing – that is, improved profitability and productivity of tree plantations in the long term.

All farmers engaged to some extent in silvicultural management, but agricultural activities were prioritized. A farmer had on average six woodlots and management would differ from woodlot to woodlot. Pruning was the most widely applied activity. Even though the level of silvicultural management was low (farmers did not apply all the silvicultural practices recommended by the program), nearly all farmers considered their woodlots to perform well enough. Farmers perceived the benefits of carrying out management (e.g. improved survival and growth). Lack of time and capital were the most common barriers to further engage in woodlot management.

Positive attitudes towards silvicultural management (i.e. farmers believe that management is only beneficial) and sceptic attitudes (i.e. farmers believe that management can also have negative effects), influenced the level of management applied. The external support from a tree-planting program and the participation in a tree-growers' association had an important role in certain management activities (i.e. site preparation, circle weeding and preparation of firebreaks). Socio-economic characteristics of the farmer and the household (i.e. age of the farmer, number of household members, number of children at school, and number of years planting trees), and characteristics of the farm (i.e. total household land area and number of permanent workers) also had an effect on the level of silvicultural management.

Several lessons from this study can be drawn upon the results, but also the author/field team's observations during the field work, and the knowledge gained throughout the elaboration of this research.

Training and technical advice on silvicultural management should be consistent, detailed, and take into account the site characteristics and the climatic conditions of tree plantations. Additionally, further emphasis should be put on the timing, frequency and intensity of the silvicultural activities. Learning by doing and demonstration of the benefits of different silvicultural management (visits to well-performing small-scale tree plantations or demonstration plots) is an effective way of learning new skills.

Tree-planting programs are likely to be most successful by developing networks and institutions able to learn, store and exchange knowledge; than by the mere supplying of free planting inputs or the sole focus on planting targets. The creation, organization and development of tree-growers' associations can help to ensure the support to farmers beyond donor-funded incentive schemes. Overall, networking between stakeholders (e.g. out-grower schemes, participatory policy making, and farmers' groups) is likely to provide the most long-term positive outcomes.

Extension (provided by donor-funded incentive schemes) must be relevant to farmers' specific interests and objectives related to tree planting. Effective extension requires that farmers receiving the extension and extension providers share similar goals. If well implemented, tree-planting programs can provide farmers with the skills and finance necessary for commercial tree planting, but without the commitment of farmers (without sharing a common goal), incentives are likely to be unsustainable – i.e. provide short-term outcomes or solutions.

Commercial tree planting requires larger amounts of time and capital than most expect. To achieve quality full-sized trees, intensive management and long rotation periods are required. For many of the farmers interviewed during this study, silvicultural management seemed dependent on the extension provided (i.e. management only in some woodlots, especially those planted with external support) and only when farmers had extra time to put into silvicultural management, after the main income generating activities were taken care of (i.e. management only some seasons).

Only time will say how many of these farmers will continue planting trees and investing in silvicultural management, beyond the incentive scheme. In any case, farmer's

perceptions change over time, depending on the markets, the new policies, and other factors shaping the entire investment environment. But, is ‘intensive silvicultural management’ a suitable livelihood strategy for all the farmers involved in this study?

It would be adequate to at least question at the beginning of any tree-planting program and for future research, which farmers should be the target for commercial tree planting. And, which extension would be the most beneficial for the poorest of the poor.

Varying kind of tree planting systems requiring different levels of management and inputs could be designed based on farmers’ objectives and capacities for joining the activity. For example, farmers with enough land, labour and resources, may be willing to maximize economic profits from tree plantations and thus a commercial approach with intensive management would be preferred. A part from having the resources available, the commercial approach is best suited for those farmers with a certain level of entrepreneurship. On the other hand, for farmers with less land, labour and resources; tree planting can serve as means to diversify or improve their livelihoods. For these farmers, other systems such as agroforestry and less intense management systems may be more adequate to satisfy their needs.

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Annex 1. Activities related to woodlot management and frequencies of farmers applying them; divided by farmers with and without the support from the major forestry program present in the study area.

	With support from a major forestry program		Without support from a major forestry program		Total	
Site establishment (% of STGs)		***n***		***n***		***n***
Just pitting	4	*95*	51	*81*	26	*176*
Clear-slash	74	*95*	33	*81*	55	*176*
Clear only the line to plant	0	*95*	12	*81*	6	*176*
Circle weeding	19	*95*	4	*81*	12	*176*
Clear by fire with firebreaks	38	*95*	7	*81*	24	*176*
Clear by fire without firebreaks	11	*95*	1	*81*	6	*176*
Removal of native trees	16	*95*	10	*81*	13	*176*
Pit size (cm)	30.6	*92*	20.5	*22*	25.6	*114*
Lining	99	*92*	97	*39*	98	*114*
Blanking	79	*92*	95	*58*	81	*114*
Application of fertilizers to eucalyptus stands (% of STGs with eucalyptus)	21	*53*	0	*53*	21	*53*
Spacing (m)	2.5	*95*	2.9	*76*	2.7	*171*
Circle weeding (% of STGs)						
No weeding applied	29	*91*	63	*19*	35	*110*
Only 1 season during last 2 seasons to some woodlots	19	*91*	16	*19*	18	*110*
Only 1 season from the last 2 seasons to all young woodlots	11	*91*	16	*19*	12	*110*
Both seasons from the last 2 seasons to some woodlots	14	*91*	0	*19*	12	*110*
Both seasons from the last 2 seasons to all young woodlots	27	*91*	5	*19*	24	*110*
Slash weeding (% of STGs)						
No weeding applied	21	*92*	10	*21*	19	*113*
Only 1 season during last 2 seasons to some woodlots	15	*92*	10	*21*	14	*113*
Only 1 season from the last 2 seasons to all young woodlots	11	*92*	33	*21*	15	*113*
Both seasons from the last 2 seasons to some woodlots	24	*92*	19	*21*	23	*113*
Both seasons from the last 2 seasons to all young woodlots	29	*92*	29	*21*	29	*113*

	With support from a major forestry program		Without support from a major forestry program		Total	
Firebreaks (% of STGs)		***n***		***n***		***n***
No firebreaks applied	12	*92*	32	*22*	16	*114*
Applied firebreaks at some point but did not maintain them	10	*92*	18	*22*	11	*114*
Firebreaks applied to some woodlots	52	*92*	32	*22*	48	*114*
Firebreaks applied to all woodlots	26	*92*	18	*22*	25	*114*
Firebreaks width (m)	7.0	*80*	5.1	*15*	6.7	*95*
Pruning						
Pruning applied or intention to do it (% of STGs)	100	*92*	100	*22*	100	*114*
Age of first pruning	3.9	*71*	4.3	*18*	4.0	*89*
Pruning times per rotation	2.5	*57*	2.4	*14*	2.5	*71*
Thinning						
Thinning applied or intention to do it (% of STGs)	62	*92*	64	*22*	62	*114*
Age of first thinning	4.3	*40*	3.8	*10*	4.2	*50*
Thinning times per rotation	1.6	*37*	1.5	*8*	1.6	*45*

Annex 2. Semi-structured questionnaire at household level.

SMALLHOLDER TREE GROWER QUESTIONNAIRE – SOUTHERN HIGHLANDS OF TANZANIA

District (*Wilaya*):_____ Village (*Kijiji*): _____

Date (*Tarehe*): _____ Starting time: _____ Ending time: _____

Interviewer (*Mhojaji*): _____ Translator (*Mtafusiri*): _____

Interview ID (*Namba ya dodoso*):_____

1. BACKGROUND INFORMATION (*TAARIFA ZA UTANGULIZI*)

1.1 First name (*Jina la kwanza*)		1.2 Last name (*Jina la mwisho*)			
1.3 Have you received support from PFP? Since when? (*Je, umepata msaada wa aina yoyote kutoka pandamiti kibiashara? Tangu lini?)*					
1.4 Do you belong to a TGA? Since when? (*Umejiunga na kikundi cha wapandamiti? Tangu lini?)*					
1.5 Specify TGA name (*Ainisha jina la kikundi cha wapanda miti*)					
1.6 Is there a VLUP? (*Je, kunampango wa kijiji wa matumizi bora ya ardhi?*)	Yes (*Ndiyo*)	No (*Hapana*)	I don't know (*Sijui*)		

2. SOCIO-ECONOMIC INFORMATION (*TAARIFA ZA KIJAMII NA KIUCHUMI*)

2.1 Gender (*Jinsia*)	Male (*Me*)		Female (*Ke*)		
2.2 Age (*Umri*)					
2.3 Head of the household (*Mkuu wa kaya*)	Interviewee (*Mhojiwa*)		Spouse (*Mwenza*)/ other (*Mwingine*)		
2.4 Marital status (*Hali ya ndoa*)	Married (*Kuoa/kuolewa*)	Single (*Sijaoa/Sijaolewa*)	Divorced (*Kuachika*)	Widow (M*jane/Mgane*)	
2.5 Education (*Elimu*)	None (*Hakuna*)	Primary (*Msingi*)	Secondary (*Sekondari*)	Higher (*Elimu ya juu*)	
2.6 Family members (living at the household) *Idadi ya watu kwenye familia (Wanaoishi kwenye kaya*)	0-17y	18-45y	>45y		
2.7 How many of the children are in school? (*Ni watoto wangapi wapo shule?*)					
2.8 Estimate the total HH income last year (2016)? In TZS (Kwa makadirio, *Pato la kaya lilikuwa kiasi gani mwaka uliopita (2016): katika shilingi ya Tanzania*)					
2.9 Was last year's income in a normal level? If "no", specify why. (*Je, Pato la mwaka uliopita lilikuwa la kawaida? Kama hapana elezea)*	Yes (*Ndiyo*)	No (*hapana*) Why? (*kwa nini*)			
2.10 Three most important sources of income last year (**in order of importance**)? (*Vyanzo vikuu vitatu vya mapato mwaka uliopita. Ukizingatia umuhimu wake?)*	1.	2.	3.		

<table>
<tr><td colspan="2">2.11 Do you or other hh members have any businesses? What kind? (Je unabiashara au Kuna mtu yeyote kwenye kaya mwenye biashara ya aina yoyote? Je ni Biashara ya aina gani?)</td><td colspan="3">If yes, make sure is included in total HH income (Kama Ndiyo, hakikisha ni sehemu ya pato la jumla la kaya.)</td></tr>
<tr><td colspan="2">2.12 During the last year have you or other hh members been working for someone? For how long? (Je, umefanya kazi kwa mtu mwingine au Kuna mtu yeyote kwenye kaya aliajiriwa na mtu mwingine mwaka uliopita? Ni kwa mda gani?)</td><td colspan="3">If yes, make sure is included in total HH income</td></tr>
<tr><td colspan="2">2.13 Do you or other hh members get any other sources of income (e.g.: remittances)? (Je, kunapato unapata au Mtu mwingine kwenye kaya anapata kutoka katika vyanzo vingine? (mfano: zawadi))</td><td colspan="3">If yes, make sure is included in total HH income</td></tr>
<tr><td rowspan="3">2.14 How many acres of land do your household have /have access to? (Ni kiasi gani cha ardhi kaya inamiliki/ tumia?)</td><td colspan="2">Cropland (Mazao)
_____acres (ekari)</td><td colspan="2">Fallow land (Lililo wazi)
_____acres (ekari)</td></tr>
<tr><td colspan="2">Settlement (Mazingira ya nyumbani)
_____acres (ekari)</td><td colspan="2"></td></tr>
<tr><td colspan="2">Tree plantations (Kupanda miti)
_____ acres (ekari)
Current owner:_____
(Mmiliki wa sasa) e.g. family
Previous owner: _____
(Mmiliki aliyepita)
Formal title? Yes/No
(Hati miliki? Ndiyo/ hapana)</td><td colspan="2">Other types of land?
(Aina nyingine za ardhi?)
Which? (Zipi?)_____
_____acres (ekari)</td></tr>
<tr><td rowspan="2">2.15 How many persons work in the farm? (hh members and paid labour) (Wafanyakazi wangapi wanafanya kazi shambani? (Wanakaya na vibarua))</td><td colspan="2">Permanent</td><td colspan="2">Temporary</td></tr>
<tr><td>Hh (wanakaya):</td><td>Paid (vibarua):</td><td>Hh (wanakaya):</td><td>Paid (vibarua):</td></tr>
<tr><td colspan="5">2.16 Do you use any machinery for your farming activities? What? (Je unatumia kifaa/mashine gani katika shughuli za kilimo? Aina?)</td></tr>
<tr><td colspan="5">2.17 Do you have livestock? Yes / No What kind?
(Je, una mifugo? Ndiyo/ hapana ya aina gani?)
Do you use them for laboring the land? Yes / No
(Je unaitumia kwa shughuli zozote? (mfano: kulimia) Ndiyo/ hapana)</td></tr>
<tr><td colspan="5">2.18 When did you start planting trees? (Ulianza lini kupanda miti?)</td></tr>
<tr><td colspan="5">2.19 Why did you start planting trees? All the reasons. (Kwa nini ulianza kupanda miti? Toa sababu zote)</td></tr>
<tr><td colspan="5">2.20 Are you content that you started planting trees? (Je, una Amani na shughuli za uapandaji miti unazozifanya?)

Since you started planting trees, now it is more or less appealing? (Tangu umeanza kupanda miti, Je inaridhisha sana au kidogo?)</td></tr>
</table>

WOODLOT MANAGEMENT (*UTUNZAJI MASHAMBA YA MITI*)

3. CHARACTERISTICS OF THE WOODLOTS (*SIFA YA SHAMBA LA MITI*) *(1 woodlot = same species, same year of establishment and same area)(1 shamba=aina sawa ya miti, imepandwa mwaka mmoja and katika eneo moja)*

3.1 Number of woodlots of the hh *(idadi ya plots*)					
3.2 What are their years of establishment (*mwaka wa upandaji*)					
3.3 Specify species,? *Ainisha aina ya miti*)					
3.4 How many of your woodlots are PFP supported? *Ni mashamba yapi yanadhaminiwa na PFP?*					
3.5 Is your woodlot located in the area designated for tree planting in the VLUP (*Je shaamba lako lipo kwenye eneo lilitengwa kwa ajili ya kupanda miti na mpango wa matumizi bora ya ardhi*)	Yes	Partially	No	I don't know	
3.6 Estimation of distance from your HH to the woodlots (*Makadirio ya umbar kutoka kwenye kaya mpaka shamba lilipo*)	Nearest (*karibu*): _____ kms		Furthest (*mbali*): _____ kms		
3.7 Have you applied agroforestry in any of your woodlots? (*Je umefanya kilimo mseto katika shamba lolote*?)	Yes / No Type of crop (*Aina ya zao*): Nº of woodlots where has been done (*Idadi ya mashamba kilipofanyiaka*):				
3.8 What former land uses were in your woodlots?(*Kabla ya upandaji miti shambaili lilikuwa linatumika kwa matumizi yapi*)	Fallow (*Eneo kwa kilimo cha kuhamahama*)	Cropland (*Shamba la kilimo*)	Pasture land (*Kwa ajili ya malisho*)	Native woodland (*Eneo la miti asili/pori*)	Other, specify (*aina nyingine, ainisha*)
3.9 Did you plant trees for: **Specify the main one** *(put "1" next to it) (malengo ya kupanda miti) ainisha lengo kuu.*	Commercial timber production (*Kwa ajili ya biashara ya uzalishaji mbao*)	Firewood/ charcoal to sell (*Kwa ajili ya kuni na mkaa*)	Own use (firewood/ construction) (*Matumizi binafsi/ujenzi*)	Other, specify(*aina nyingine, ainisha*)	
3.10 Seedling source (*Mnapata wapi miche*)	PFP	Local nursery (*Kienyeji)*	Major commercial nursery (*za kitaalamu*)	Other, specify (*aina nyingine, ainisha*)	
3.11 Have any of your woodlots been seriously affected by: (*Je shamba lako limedhuriwa kwa kiasi kikubwa na:)*	Fire (*Moto*)	Insect damage (*wadudu waharibifu*)	Other, specify (*aina nyingine, ainisha*)		
3.12 Have you received any support in your woodlot establishment or management? What kind, from who and how much in total (more than once?) (*Je umewahi pata msaada wa aina yoyote katika utunzaji wa mashamba? Aina gani, kutoka kwa nani na kwa kiasi gani kwa ujumla?)*	What kind? (*Aina gani?*)	From who? (*Kutoka kwa nani?*)	How many times? (*Mara ngapi?*)		
	Credit/loan (*Mkopo*)				
	For what did you use the loan/credit? *Umetumia kufanyia kitu gani mkopo huo*?				
	Cash (*Pesa taslimu)*				
	For what did you use the cash? (*Pesa taslimu meitumia kufanyia kitu gani?)*				

	Free/subsidized seedlings (*Miche ya ruzuku/bure*)		
	Fertilizers (*Mbolea*)		
	Others, specify (A*ina nyingine, ainisha)*		

4. REPORTED MANAGEMENT ACTIVITIES (*SHUGHULI TAJWA ZA UTUNZAJI WA MITI*)

Site establishment (*Kuanzisha eneo*)

4.1 How have you established the site? (*Umewezaje kuanzisha eneo*)	1. Clearing/Slashing *(Kufyeka*)	2. Pitting (*Kuchimba mashimo*):	Pit size:	
	3. Herbicides *(Dawa za wadudu*)	4. Lining (*Pangilio*)	5. Blanking (*Kurudishia*)	
	6. Fertilizer (*Mbolea*)	7.Other, specify (*Aina nyingine, ainisha*)		
4.2 What planting spacing have you applied? (*Unaacha nafasi kiasi gani kati ya mche na mche*?)				
4.3 Who did the above mentioned activities? (*Nani amefanya shughuli hizo zilizotajwa?)*	Household member(s) (*Wanakaya*)	TGA cooperation (*Kikundi cha wapandamiti*)	Paid labour (*Kibarua*)	

Weeding (*Palizi*)

4.4 During the last 2 years have you done: (*Je ulifanya yafuatayo katika msimu miwili ya ukuzaji*)	2015/2016 (times/year) (*Mara ngapi kwa msimu/mwaka*)	2016/2017 (times/year) (*Mara ngapi kwa msimu/mwaka*)	
Circle weeding (*Palizi kuzunguka miti*)			
Slash weeding (*Kufyeka*)			
4.5 Who did the above mentioned activities? (*Nani amefanya shughuli hizo zilizotajwa*?)	Household member(s) (*Wanakaya*)	TGA cooperation (*Kikundi cha wapandamiti*)	Paid labour (*Kibarua*)

Fire breaks (*Kutokea kwa moto*)

4.6 Are your woodlots protected by a fire break? (*Je mashamba yako lyamelindwa na njia za kuzuia moto?)*	Yes / No (*Ndiyo/ Hapana*)	Width (*Upana*): _____ m	Nº of woodlots where this protection has been done: (*Idadi ya mashamba ambayo yamelindwa)*	
4.7 Did you do fire break maintenance last year?				
4.8 Who did the above mentioned activities? (*Nani amefanya shughuli hizo zilizotajwa?)*	Household member(s) (*Wanakaya*)	TGA cooperation (*Kikundi cha wapandamiti*)	Paid labour (*Kibarua*)	
4.9 Do you do something else in order to reduce the hazards				

from fire? What? (*Je kuna kitu kingine chochote unafanya kupunguza majanga ya moto? Aina gani?*)	

Pruning (*Kupogolea*)

4.10 Have you ever applied pruning? (*Ulishawahi kupogolea*?)	Yes (*Ndiyo*)	No (*Hapana*)	Age of first pruning: How many times: (*Mara ngapi na kaika umri gani?*)	Species: (*Aina*)
4.11 Who did the above mentioned activities? (*Je Nani aliyefanya shughuli tajwa hapo juu?)*	Household member(s) (*Wanakaya*)	TGA cooperation (*Kikundi cha wapanda miti*)	Paid labour (*Vibarua*)	

Thinning (*Kupunguzia*)

4.12 Have you ever applied thinning? (*Je umeshawahi kupunguzia miti yako*?)	Yes (*Ndiyo*)	No (*Hapana*)	Age of first thinning: How many times: (*Mara ngapi na kaika umri gani?*)	Species: (*Aina*)
4.13 Who did the above mentioned activities? (*Je Nani aliyefanya shughuli tajwa hapo juu?)*	Household member(s) (*Wanakaya*)	TGA cooperation (*Kikundi cha wapanda miti*)	Paid labour (*Vibarua*)	

Final cut

4.14 At what age are you planning to clear fell (Unavuna miti katika umri gani kwa aina ya miti?)	Age:	Species:
	Age:	Species:

Markets

4.15 How have you sold your trees / How are you planning to sell your harvested trees? Je, uliwezaje kuuza mavuno ya miti yako / umepanga kuuzaje mavuno ya miti yako? (hints: market, middleman or companies)	

5. EXTENSION (*UGHANI*)

5.1 Did you receive any technical instructing or training in woodlot establishment and management? Yes/No (*Je umeshawahi kupata msaada wowote wa kitaalamu/ Mafunzo kuhusiana na upandaji na utunzaji wa mashamba ya miti? Ndiyo/Hapana)*	**Plantation phase/activity, how?** (*Katika hatua gani, shughuli gani na ilifanyikaje*?)	**Organization (NGO, TGA, government, etc)** (*Taasisi)*	**Usefulness of service (1 – 5) 1 (not useful) 5 (very useful)** (*Manufaa)*
What topic and who? *(Aina ya utaalamu/mafunzo na*			

ulipewa na nani?) (planning (mipango), species/site selection (kuchagua eneo) wa shamba), site preparation (uandaaji wa shamba), establishment (kupanda), blanking (kurudishia miche), weeding (palizi), pruning (kupogelea), thinning (kupunguzia miti), fire breaks (njia za kuzuia miti), marketing/ selling (masoko), final cut (uvunaji), etc)			
5.2 From where have you got any information related to woodlot establishment and management? (*Ni wapi unapata taarifa kuhusiana na utayarishaji na utunzaji wa shamba lako?*)	School (*shule*)	TGA (kikundi cha wapanda miti)	PFP (Panda miti kibiashara)
	Other programmes (Mashirika/miradi mingine)	Companies (Makampuni)	TV (Luninga)
	Radio PFP? Yes / No	Newspapers/magazines(Magazeti/majarida)	Relatives or friends (Ngugu/marafiki)
	Government (regional, district) (Serikali)	Church (*Kanisa*)	Other, specify

6. RATIONALE (*HAJA*)

6.1 General

	Agree (*Nakubali*)	Disagree (*Nakataa*)	I don't know (*Sijui*)
6.1.1 More trees per acre, the better (*Miti mingi kwa ekari ni vyema*)			
6.1.2 I rather have many small trees than fewer big trees (*Ni bora kuwa na miti mingi midogomidogo kuliko mikubwa michache*)			
6.1.3 I rather wait 14 years to harvest when trees are big than harvest early at 7 years when trees are small *(Ni bora kusubiri miaka 14 ili kuvuna pale miti inapokuwa mikuwa kuliko kuvuna mapema ndani ya miaka saba wakati miti ni midogo*)			
6.1.4 If my trees are straight and have few branches, I can get better price for them (*Kama miti yangu imenyooka na ina matawi machache nitapata faida nzuri*)			
6.1.5 Tree seedlings from improved seeds are much better than tree seedlings from local seeds (*Miche kutoka mbegu bora ina ubora kuliko miche inayotoka katika mbegu za asili*)			
6.1.6 Seedlings obtained from major tree nurseries are much better than seedlings obtained locally (*Miche kutoka katika vitaru vya kisasa ni bora kuliko miche kutoka vitaru vya kienyeji*)			
6.1.7 My trees could grow better if I had more time to spend working with them (*Miti yangu ingeweza kustawi vema kama ningetenga mda mwingi kwa ajili ya kuihudumia*)			
6.1.8 My trees could grow better if I had more money to allocate to them (*Miti yangu ingeweza kustawi vema kama ningekuwa na pesa ya kutosha kuihudumia*)			
6.1.9 My woodlot is so far away that its management is difficult (*Shamba langu liko mbali kiasi kwamba ni vigumu kulihudumia*)			

6.1.10 The other tree growers manage their woodlots the same way as me (*Wapandamiti wegine hutunza mashamba yao kama nifanyavyo mimi)*			
6.1.11 I feel confident with the land tenure/ownership of my woodlots (*Nina uhakika na umiliki wa shamba langu la mit*i)			
6.1.12 I would need more instructions/extension services to manage my woodlots better (*Nitahitaji maelekezo zaidi ya kitaalamu kuweza kutunza shamba langu*)			
6.1.13 My woodlots are in good condition and grow well (*Shamba langu liko kwenye hali nzuri na linaendelea vizuri*)			

6.2 Site preparation (*Maandalizi ya eneo*)

	agree	disagree	I don't know
6.2.1 The size of the pit does not make a big difference to performance of the seedlings (*Ukubwa wa shimo la kupanda mti hauleti utofauti mkubwa kwa ustawi wa mche*)			
6.2.2 The better the slashing during site preparation, the better the growth of the planted trees (*Ufyekaji stahiki wakati wa uandaaji wa shamba Ndiyo ustawi mzuri wa miti)*			

6.3 Weeding (*Palizi*)

6.3.1 Why did you do weeding? (What benefits do you see in weeding?) (*Kwa nini unapalilia shamba lako? Nini faida za kupalilia shamba lako?)* Did you decide yourself to do weeding or were you instructed to do so? By who?(Je, uliamua mwenyewe kufanya palizi au ulielekezwa kufanya hivyo? Na nani?) - Why did you not do weeding? (*Kwa nini hukupalilia shamba lako*?)			
	Agree (*Nakubali*)	Disagree (*Sikubali*)	I don't know (*Sijui*)
6.3.2 I think I have good skills/knowledge on how to do proper weeding *(Nadhani nina ujuzi wa kutosha wa namna ya kufanya parizi kwa ufasaha)*			
6.3.3 There is no other benefits from weeding apart from making accessibility to the woodlot easier (*Hakuna faida yeyote itokanayo na palizi, mbali na kurahisisha upitikaji wa shamba la miti)*			
6.3.4 More weeding, the better the growth of trees (*Parizi Zaidi ustawi mzuri wa miti)*			
6.3.5 Weeding makes trees grow faster (*Parizi ufanya miti kukua haraka*)			
6.3.6 Weeding reduces competition for nutrients (*Parizi upunguza ushindani wa virutubisho*)			
6.3.7 Weeding makes the soil dry (*Parizi hukausha udongo*)			
6.3.8 Some trees may die because of weeding (*Miti mingine huweza kufa kutokana na parizi*)			
6.3.9 Some trees may die if weeding is not done (*Miti mingine huweza kufa kama parizi haitafanyika*)			

6.3.10 Weeding is too time consuming compared to the benefits *(Parizi hutumia mda mwingi ukilinganisha na faida zake*)			
6.3.11 Weeding is too expensive compared to the benefits (*Parizi ni gharama ukilinganisha na faida zake*)			
6.3.12 Weeding of eucalyptus plantations is much more important than weeding of pine plantations (*Parizi ya mashamba ya mikaratusi ni ya mihimu kuliko parizi ya mashamba ya misindano)*			
6.3.13 Weeding reduces fire hazard (*Parizi hupunguza majanga ya moto*)			
6.3.14 In general I think that weeding should always be done(*Kwa ujumla nadhani parizi hutakiwa kufanyika mar azote*)			

6.4 Fire breaks (*Kudhibiti moto*)

6.4.1 Did you decide to prepare the fire breaks or were you instructed to do so? By who? (Je, uliamua mwenyewe kuandaa vizuizi (barabara za) vya moto au ulielekezwa kufanya hivyo? Na nani?) - Why did you not prepare fire breaks? (Kwa nini hukuandaa *njia za kuzuia moto?*)	
6.4.2 Is fire a main concern (major hazard) for the future of your woodlots? (*Je moto ndiyo changamoto kubwa kwa maendeleo ya baadae ya shamba lako?)*	

6.5 Pruning (*Kupogorea*)

6.5.1 If you have not done pruning, are you planning to do it? (*Kama hujapogolea je una matarajio ya kufanya hivyo?)*	Yes (*Ndiyo*)	No (*Hapana*)	
6.5.2 Why did you do pruning / planning to do pruning? (*Kwa nini ulipogolea/unatarajia kupogolea*) Did you decide yourself to do pruning or were you instructed to do so? By who?(Je, uliamua mwenyewe <u>kupogorea</u> au ulielekezwa kufanya hivyo? Na nani?) - Why did you not do pruning / not planning to do pruning? (*Kwa nini hujapogolea/Hutarajii kupogolea*)			
	Agree (nakubali)	Disagree (Sikubali)	I don't know (Sijui)
6.5.3 Doing pruning increases the total revenues from my woodlot (*Kufanya upogoleaje inaongeza pato kutoka kweye shamba*)			
6.5.4 Pruning increases quality of timber (*Kupogolea kuaongeza ubora wa mbao*)			
6.5.5 Pruning is too time consuming compared to the benefits (*Kupogolea utumia muda mwingi ukilinganisha na faida zake*)			
6.5.6 Pruning is too expensive compared to the benefits (*Kupogolea ni gharama ukilingaisha na faida zake*)			

6.6 Thinning (*Kupunguzia*)

6.6.1 If you have not done thinning, are you planning to do it? (*Kama haujawahi kupunguzia, je unataraji kufanya hivyo?*)	Yes (*Ndiyo*)	No (*Hapana*)

6.6.2 Why did you do thinning / planning to do thinning? (*Kwa nini umepunguzia/unapanga kupunguzia*?) Did you decide yourself to do thinning or were you instructed to do so? By who? (Je, uliamua mwenyewe kupunguzia miti yako au ulielekezwa kufanya hivyo? Na nani?) - Why did you not do thinning / not planning to do thinning? (*Kwani haujapunguzia/Hutarajii kupunguzia*?)	

	Agree (N*akubali*)	Disagree (*Sikubali*)	I don't know (*Sijui*)
6.6.3 Doing thinning increases the total revenues from my woodlot (*Kupunguzia huongeza pato la ujumla kwenye mashamba yangu*)			
6.6.4 Thinning is too time consuming compared to the benefits (*Kupunguzia hutumia mda mwingi ukilinganisha na faida zake*)			
6.6.5 Thinning is too expensive compared to the benefits (*Kupunguzia ni gharama ukilinganisha na faida zake*)			
6.6.6 I don't think there will be a market for pine trees harvested in thinning (*Sidhani kama kutakuwa na soko la misindano iliyovunwa wakati wa kupunguzia*)			
6.6.7 I don't think there will be a market for eucalyptus trees harvested in thinning (*Sidhani kama kutakuwa na soko la mikaratusi iliyovunwa wakati wa kupunguzia*)			
6.6.8 Thinning is only good to increase the volume of trees left in the woodlot, but it does not provide me any extra revenues. (*Kupunguzia husaidia tu kuongeza ukubwa wa miti iliyoachwa shambani lakini haileti mapato ya ziada*)			

7. Future scenarios (*Matarajio ya baadae*)

7.1 What type of support would you need in order to manage your woodlot better? (*Ni aina gani ya msaada ungehitaji ili kutunza shamba lako vyema?)* Choose first and second most relevant. (Fill in with 1 and 2) *Remark: annotate for what they would use the support.*	Loan (*Mkopo*) Cash (*Pesa taslimu*) Training (*Mafunzo*) Labour force (*Nguvu kazi*) None (*Hakuna*) Others: (*Mengineyo*)
7.2 If in 5 to 10 years there is a situation where you need cash, from where would you get it? (*Kama miaka 5 hadi 10 ijayo ikatokea unahitaji fedha, je ni mahali gani unaweza kuzipata kirahisi*?)	
7.3 Can you think of a way that you wouldn't have to harvest your trees when cash is needed? (*Je unafikiri ni njia gani itasidia kuepuka kuvuna miti pale utakaohitaji fedha?)*	
7.4 Would you decide not to harvest if you had the possibility to apply for a loan? (*Je unaweza kuamua kutovuna kama kuna uwezekanao wa kuomba mkopo?)*	
7.5 Have you considered the possibility to grow legumes during the first couple of years of the plantations, why not? (*Je ushawahi fikiri uwezekano wa kuchanganya mazao kwa kipindi cha mwanzo wa upandaji katika mashamba yako? Kama hapana kwa nini?)*	

7.6 How would you like to see yourself/do you see yourself in 10 years from now? (*Unajiona namna gani miaka kumi ijayo kutokea sasa*?)	

Annex 3. Field survey

FIELD SURVEY – STP IN SOUTHERN HIGHLANDS OF TANZANIA

District: _____ Village: _____ PFP_ben:_____ Date: _____

Woodlot owner: _____ Interview ID:_____ Survey nº:____

GENERAL WOODLOT DATA

1. Coordinates by GPS

							N
							E

2. GPS accuracy: ____ m

3. Elevation from sea level: _____ m

4. Planting year and month: _____ _____

5. Species: _____

6. Total area of the woodlot: _____acres

7. Distance from the household / village centre: _____ kms

8. Distance from the nearest road: _____ kms

9. Slope: _____%

10. Woodlot location:

Hilltop	Slope	Valley bottom

11. Site description:

Presence of ferns	Yes	No
Height of weeds	m	
Color of soil		

PLOT MEASUREMENT

12. Number of trees alive in the plot: ☐

13. Number of trees dead in the plot: ☐

14. Total number of trees in the plot: ☐

15. Total number of stumps in the plot (commercial ☐ species):

16. Height of tallest tree (in decimetres):____dm, Second tallest tree: ____ dm

17. In case there are dead/bad condition trees, assess the likely main cause of death:

Suppression by weeds	☐	Drought stress:	☐
Fire damage	☐	Off-site	☐
Cattle trampling:	☐	Other (insects, disease):	☐

WOODLOT OBSERVATIONS

18. Presence of yellow needles/leaves	Not at all	Slightly present	Present	Highly present
19. Presence of trees damaged by insects/fungi	Not at all	Slightly present	Present	Highly present
20. Presence of trees damaged by fire	Not at all	Slightly present	Present	Highly present
21. Presence of forked trees	Not at all	Slightly present	Present	Highly present
22. Presence of swept trees	Not at all	Slightly present	Present	Highly present
23. Presence of other deformations (bended trees, fox-tail, etc)	Not at all	Slightly present	Present	Highly present

24. Level of circle weeding in the woodlot: ☐

25. Level of slash weeding in the woodlot: ☐

Scale:
0 – No weeding done
1 – Some weeding done, but not acceptably
2 – Weeding activities done acceptably
3 – Weeding activities done completely

26. Presence of firebreaks: Yes / No

In direct contact with the woodlot: Yes / No Width: _____ m

27. Evidence of pruning done: Yes / No

Cut quality:

Poor	Average	Good

28. DBH in older woodlots: *(Measure DBH of every third tree, start in a randomly chosen tree and move forward clockwise)* → Record about 7 DBHs:

29. Other observations:

Include pictures of the woodlot. ID number of the pictures: